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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors, the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Governmental Requirements and Patent Rights.—In an extreme view of the rights of inventors, many people almost lose sight of the tenures under which monopolies formed by *letters* patent are held; that such (so-called) patents are grants or gifts justified solely by public policy, in the encouragement and accomplishment of novel industries and arts, and limited by statute in various ways, especially in duration of holding. Beside the statutory limitations, there are common law ones founded on the older English jurisprudence. Thus, no *patent* could be supported in any of our courts in restriction of the right to use an implement of warfare, or to use any other invention needed by government for any of the purposes of defense or armament, the patented object occupying the same position with other private property, namely, that of subserviency to the exigencies of the commonwealth.

The *right* of ownership to an invention, in the strict sense of right, is an exceedingly slender one. In this country, it attaches to original invention only (the fact of accomplishment not having due force as yet in our legal decisions) while generally, elsewhere, introduction combined with novelty is requisite.

Every child invents anew and originally all the processes of daily life, from the combination of the hammer with the looking-glass (if chance gives him possession of these coveted objects of childhood) upwards. Every schoolboy of aptness in mechanical application, invents from the description of his books, apparatus and contrivances in advance of his lessons. In fact, the chief interest in his studies is found in the excitement of application they suggest. Every apprentice in the workshop, who ever comes to be. a workman, invents at least one steam engine or loom, explores a perpetual motion, and constantly finds new ways, to him, to perform what he sees going on about him, or what he is called upon to do for himself. The practical workman is no better off in his field of invention. Each skillful process which he accomplishes, beyond the bare skill of manipulation in regular task work, is an effort of invention; frequently, it may be said generally, exceeding in merit the greater number of those which bring (un-) merited rewards in the lottery of the patent office.

There comes a pang of regret to every draughtsman or mechanic, when he finds his thoughts and labors have been anticipated and possibly excelled by others. The student, the philosopher, or the literary man experiences the same, on coming to the knowledge that he has burnt the lamp, solved the difficult problem. annunciated the labored thought, and that others more comprehensive, more ingenious, or more eloquent, have beaten the paths, until, perhaps, not a stone is left upon them, or even a spear of grass to be trodden down. The mechanic is less fortunate than these, not only,

> "But knowledge, to their eyes, her ample page
> Rich with the spoils of time, did ne'er unroll;
> Chill penury repressed their noble rage,
> And froze the genial current of the soul."

But the "ample page" records only a very little of the practice, and explains yet less of the theory of his vocation. The professor or the book-writer have far more to learn from the workman than the workman from them. It is an unsatisfactory comment on the relationship of the workman and the inventor, to knowledge, and to the adminis-

tration of our patent laws, that the less a man knows, the more he can patent.

The evident limiting consideration of *right* to invention altogether, lies in the certainty that any and all inventions of value will be invented by some person at some time when circumstances and time develop the necessity. In fact, the settlement by our courts to-day, of the claims of patentees whose inventions (?) have just come to fructuation—inventions which have been matters of record in advance for years, decades, centuries, and in instances of actual occurrence, for milleniums, but have failed to have common usage of to-day, for want of requirement in our dark ages, is one of the knottiest problems of special pleading, calling for the most ingenious of expert perjury.

If it were not to a thinking man a very painful exhibition of futile aspirations, it would be amusing to listen to a patentee, the tenure of whose patent rests upon the accident of the presumed first application of a common device, discourse on thieves, pirates, highway robbers, when one knows that the least investigation into the practice of those who have filled similar requirements elsewhere, will develop that fatal want of originality, before which the *right* will disappear, and "leave not a rack behind."

The most enthusiastic inventor and patentee recognizes that his right must and should terminate as certainly as his own life. He knows that his own invention is founded upon prior ones, innumerable; and immeasurably more important. He can have his apple and eat his apple, and it is gone, but the seed is the property of mankind. The patent rights of Tubal Cain have ages since expired. However unwillingly the concession may have been made, the inventor acknowledges some common claims of mankind to the industries and arts of ages, only claiming a superiority, not probably in actual *knowledge* of all that has been done before him, but in perception of mechanism, since the world began.

The manufacturer is more willing to deny the ideal or inventive property, and is often dubious whether his industry, capital, or goodwill, either earned by perhaps a lifetime of work and care, or inherited from previous earnings, ought of *moral* right to be supplanted or destroyed by the changes of some small, but essential detail of his processes of work; still, with restrictions as to duration, he may, on general grounds of development and growth, assent to patent rights,

trusting that he may secure to himself the advantages of the resulting monopoly, or at the worst show such fight as will eventuate in a share of the spoils.

The community as represented by the government of the land (for the press representation is subsidized by advertisements completely to the patent interest), has not very fully weighed the two sides of the question, but has decided for the present that if any need of art or industry occurs, the first claimant shall have an exclusive right against all others, for the magical number of seventeen years, regardless alike of the obvious nature of the claim, and of any effort to introduce or develop a result. And having thus established a legal patent right, on the same grounds that public defense may require the use of articles or processes covered by patents, the public welfare does (or may be assumed to) demand, or at least make it desirable to require, that private citizens shall in some cases use things patented.

One of the primary duties imposed upon Congress by the constitution, is the regulation of commerce, not that the duty of a supreme government is derived from the constitutional stipulation or covenant, but that by this delegation of authority, Congress is elevated to a supremacy of government. The performance of this duty, the protection of persons and of property, the collection of revenues, and the expenditure of the same, calls for enactments, general and special, to satisfy all and each undertaking, or direliction which may be incident to the traffic of the nation. If Congress finds in the course of legislation, there is known to exist any one article or process calculated to facilitate commerce, or protect the traveler or property in transit, to secure returns to the treasury, or in otherwise be exigent to the country, then the *right* to require the use of such article or process, patented or otherwise, is a foregone conclusion.

Whether the patentee, either by absolute refusal, or by establishment of excessive or any values, possesses a *right* to prevent the fulfilment of the law, would seem a question equally easy to decide, and it becomes eminently proper to consider in what way an enforcement of legal requirement can be made without hardship to the patentees, or burden to the user.

There are two points of view from which to look at these questions. The *first* one is founded on the absolute rights of the community in contradistinction to *grants* to patentees. A man cannot lose that which he never had. If it be enacted, that in all future grants of

patents, the public right of usage, manufacture and sale, for any specified purpose of governmental requirement, by law, shall be reserved as free and common to all citizens, the question is decided for all time hereafter. This simple, radical and effectual remedy is not offered here as the advisable, or perhaps the entirely equitable course to be pursued, but it can be affirmed to be more fair and liberal to the patentee than has been or is his course to the government or community on the opposite side of the transaction. The nation can afford to be generous and liberal in its dealings with inventors, and even if the course of law should be modified as above, the claim of real merit is certain to be heard. A public benefactor, who has earned a public reward, is sure to receive it.

This course, however, may be somewhat at variance with the adopted policy of the nation, and the *second* aspect of the case may be more favorably regarded. The necessity of laws enforcing the use of patented articles or processes by private individuals, having been admitted, the public right to require a surrender, in some senses, of the patent grant, is consequent, and in continuation of the argument, it would seem that public expenditure ought to commute the damages to the patentee. In other words, if it be required by law to use or provide anything, the manufacture, sale or usage of such thing shall be free and unrestricted for the required purpose; and if the requirement involves the deprivation of any private rights, they (the rights) shall be satisfied by public compensation; or, on the other hand, if the requirement involves the resumption or restriction of any grant, wholly or in part, the right of resumption or restriction for these purposes shall be one of the understood conditions of the original grant, and the equitable value of that portion of the grant resumed or restricted, shall become a claim against the United States, to be settled by action in the Court of Claims, in the usual course of procedure in that court.

This final proposition, that government should restrict its original grant, and assume full ultimate consequences of any loss in its pecuniary aspect, may be novel, but it is thought that a consideration of its effect upon the three parties interested, will exhibit advantages to each, and demonstrate itself to be a more equitable solution of the problem than has been before offered. Let it be a condition (in emendation of the patent laws), precedent to all future grants of patents; of the retention of the right of government *for* its own purposes, or *for* lawful requirement of use, to free the manufacture, sale

or use of the thing wanted or required; and although it may be inferred from what has before been said in this paper, that government already possesses the right to limit or restrict a patent now in existence, when it is deemed sufficiently necessary to the public welfare or service to require its public use, it will be better possibly, to provide on articles now patented, that such public use shall not be enforced until the patentee relinquishes his claims of monopoly.

With these principles of law firmly established as a ground of action, a committee of Congress can enter upon a comparatively unbiased consideration of the mechanical means available for the protection of life, of property, or the attainment of any of the ends of commercial or national legislation. The proposition or the counsel of the engineer or scientific man will once more have weight in determining the laws. It will cease to be for the interest of mere speculators, to fasten (like leeches) on commercial transactions which Congress may be called upon to regulate or control. And although a perfect system of laws may not immediately result, at least one cause of very bad laws will be removed.

The effect on purchasers and users will be singularly grateful. That the burden and cost of public requirement for the public good will have been removed from the shoulders of the few, will be fully appreciated. But even this burden has not been the most onerous or annoying. What has been specially vexatious, has been the foolish, unnecessary requirements foisted upon some of our greatest commercial interests, under pretext and color of promotion of the public welfare. Take, for instance, the steamer laws; it may be safely affirmed, that to this present time, the patent system has not produced any invention reducing materially the insecurity of the boiler, and from all the attachments demanded by law, which may have been attached, there has only resulted a reduction of the responsibilities of the firemen, engineers, or *owners*. The Tice Meter is a case in point, keenly appreciated by the distillers. The hardship of having an arbitrary, fictitious value set upon an article of necessity, is one of the least of tolerable ones; and patent owners have not been reluctant to take advantage of their right.

In this matter of protection of commerce, the interest of the common carrier is identical with that of the public. Competition for price might occasion some disregard of safety, but a universal requirement puts all competitors on the same level of expenses, and

the belief that enactments are for public good, and not for private advantage, will associate on a mercantile basis, as well as upon the sentiment of justice; those who are to be governed by the law, with those who make the law, in one quest of the best, most lasting, most suitable for the intended purposes.

In the bidding for government contracts for the supply of patented machines or apparatus, a competition under the system proposed will become a reality, and an advertisement for proposals something more than a farce. Whatever mistake or absurdity may attach to all government proposals, from indiscriminate bidders, there are none so great or ridiculous as those for what only one person can supply; and generally it may be said *he* never takes the trouble to respond. Certain of his sale, and of the government purchase, the patentee allows others to bid at any rate they may get, and sells to the fortunate competitor at his fixed price, avoiding the odium attached to a contractor; and superior in his honesty, when that contractor has been found out in obtaining a merchant's profit.

But to the patentee the new plan offers a positive reward. Very little of the proceeds of any sales made in accordance with the law has ever reached him. It is the rarest case where the patentee is the manufacturer or even the licenser in receipt of a fair royalty. In the incipiency of the proposed law, he will, he must have parted with most, if not all, his interest for lobby and generally fraudulent demands. Speculators will have preyed upon him at every point. An advertising notoriety must have been attained at great cost—testimonials have been manufactured—scientific evidence *prepared*—rival claims settled, these latter being more formidable in proportion as his own invention was more meritorious; and, finally, after the traveling expenses, cost of dinners and suppers to worthless men in Washington, etc., etc., have been defrayed; the inventor's share, *the reward of* GENIUS, will have dwindled away, almost to the status of his claim for novelty. Under the new plan, on the other hand, if it shall be evident that an invention will so fill a public requirement as to justify adoption and compulsatory use, the claim of the inventor will follow the course of all just unsettled claims against the United States. With suitable and special provision he, and he alone, can obtain payment; the amount of which will be fixed and established by judicial evidence before a competent tribunal; and the final reference to Congress, in appropriation, will complete the protection of the treasury, to the satisfaction of the most economical reformer.

The Water Commission.—In accordance with a request, the following recommendations of the Commission of Engineers on the water supply of Philadelphia is here published in full for the benefit of the readers of the JOURNAL.

RECOMMENDATIONS.

These may be considered in two parts; those relating to the more immediate requirements of the city, and those which belong mainly to the future. Among the former are:

1. The completion of the East Park Reservoir, and connecting it by 48-inch pumping mains with the works at Spring Garden and Fairmount, and by distributing mains of the same size with the Spring Garden, Corinthian, and Delaware Reservoirs.
2. The improvement of the machinery at Fairmount, and the building of two improved turbines.
3. The erection of a pumping engine of 10 million gallons capacity at the Spring Garden Works.
4. Re-arranging the pumping mains at the Belmont Works, and putting in a proper distributing main from Belmont Reservoir to supply the east side of the river.
5. The building of an intercepting sewer on the east side of Fairmount Pool, or of a conduit for purer water from Flat Rock Dam to the pumping works at Belmont, Spring Garden, and Fairmount.
6. The extension of the inlet pipe at the Kensington Works into deeper water.
7. The raising of the Delaware Reservoir six feet.
8. The establishment of a new pumping station at Lardner's Point, with a reservoir at or near Wentz Farm, with proper mains connecting the pumping works with the Delaware Reservoir, and with the new reservoir supplying Frankford, etc.
9. The consideration of the purchase and use of water-power at Manayunk, and the construction of the proposed new works dependent thereon.

It is not expected that all of these will be finished in 1876; but enough may be accomplished to improve the quality and add to the quantity of the water supply during the Centennial year.

The completion of them all would both increase the quantity and improve the quality of the water supply of the city, to a very great extent.

PROVISION FOR CENTENNIAL YEAR.

To provide for the Centennial year we recommend the immediate completion of the alterations and improvements of the present wheels at Fairmount; the erection of a ten million engine at the Spring Gar-

den Works; the extension of the inlet pipe at the Kensington Works; and the completion of the East Park Reservoir and its connecting supply and distributing mains.

And in view of the delay in building an intercepting sewer, the discharge from the breweries and the sewage in the vicinity of the Spring Garden Works should receive immediate attention.

In regard to the future, our investigations show that there is only one of the proposed plans for bringing water from a distance which seems to be reasonably practicable, namely, the Perkiomen Reservoir and Conduit scheme, as presented in this report. The proper time for entering upon a work of such magnitude, requiring so large an expenditure of money, will necessarily depend in some measure upon the action of Councils on the subject of the works we have recommended to their consideration, and also upon the success which may be met with in maintaining a satisfactory supply of good water by the means we have indicated.

Raising Fairmount and Flat Rock Dams.

It has been suggested by Mr. James F. Smith, Chief Engineer, in his paper contained in the appendix, that the dams at Fairmount and Flat Rock might be advantageously raised, and we commend this subject to the consideration of Councils.

Science and Art at the South Kensington Museum, London.—A circular issued by a committee of the most eminent men in the different branches of science and art, gives notice that a Loan Exhibition of Scientific Apparatus will be opened at the Museum on the 1st of April, 1876, and remain open until the end of September, after which time the objects loaned will be returned to the owners. It will consist of instruments and apparatus employed for research, teaching, illustration of progress of science or application to the arts, etc., etc. As far as practicable, arrangements will be made for explaining and illustrating the objects which may be exhibited, and their purposes. The cost of carriage of all the objects selected for exhibition, will be defrayed by the Science and Art Department. The entire range of mechanical or physical application is covered by the prospectus of the committee, which can be seen on the tables of the Franklin Institute, together with forms and other information for those who desire to exhibit.

THE EFFECT OF ELECTRIC FORCE ON THE MATERIAL OF STEAM BOILERS.

DEAR SIR:—In the November number of the JOURNAL, which has just reached me, I have been attracted by your note on page 345, following Dr. Cresson's paper "on the effect of magnetic and galvanic forces upon the strength of, and destruction of iron and steel structures." The notion that the destruction of iron boilers by corrosion when supplied with ordinary water is ascribable to galvanic action, has, in my opinion, very little foundation in fact. Some samples of iron corrode more readily than other samples, but they will do so when submitted to any of the conditions favorable to such slow combustion. In my experience as a locomotive engine builder and more recent observations I have never seen any good reason to abandon the common practice of uniting metals of known different electro-conditions in one structure, and will cite what you must have overlooked as you do not mention it in your note, viz.: the use of cast iron boiler heads, cast iron man-hole rings in connection with wrought iron shells. Also in locomotive practice of wrought iron boilers with copper tubes, and even copper fire boxes. Some such boilers being of undoubted long life. So with many instances of boilers with brass tubes and all the fittings such as hand hole plugs are made of brass. I imagine that any of these metals so placed in connection with one another as to form a galvanic battery of usual construction, and then immersed in a bath of such water as is usually used in boilers, that the electric or galvanic currents obtainable from such, a construction would be a very feeble and that no "strong galvanic action" would take place. I like to see all theories substantiated by facts, but the facts should be viewed equally not unequally. Electricity is dragged in too often to account for phenomena that could be explained in other ways. You are quite right in saying that "it is a serious mistake to admit as a popular utterance, that we must look to 'galvanic (voltaic ?) force' as the *cause* of deteriorations of boilers, or of iron structures of any kind." I do not wish to say that it has nothing to do with it under certain conditions, but that it plays any such important part as to make us avoid combinations of metal of great mechanical advantage when combined, for fear that some grand galvanic action will destroy the structure so built up, when we all know well enough that such combination of dissimilar metals have stood the test of years, and will continue to be used with safety in good engineering practice.

3301 Baring St., Nov. 5, 1875. COLEMAN SELLERS.

Errata.—It will be noticed that the number of this JOURNAL on the cover is 600 in place of 599, in (regular sequence). There was an error committed in August and September, 1870, both of which were numbered 536, and this correction is now made so that the next year shall commence properly, number 601, there having been 600 numbers actually completed by this present one.

Correct page 358, lines 21 and 22, for A,—A,—A, read N,—N,—N.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 17th, 1875.

The stated meeting of the Institute was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers in the chair.

There were present 227 members and 7 visitors.

The minutes of the last meeting, held October 20th, were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their meeting, held on the 10th inst., the following donations were made to the library:

Report on the Water Supply for the City of Philadelphia, made by the Commission of Engineers appointed by the Mayor, under the ordinance of Councils, approved June 5th, 1875. Philadelphia, 1875. From Solomon W. Roberts.

Laws governing the steamboat inspection service. Revised statutes of the United States. Washington, 1875.

General rules and regulations prescribed by the Board of Supervising Inspectors of steam vessels, and approved by the Secretary of the Treasury. 1875.

Proceedings of the Twenty-third Annual Meeting of the Board of Supervising Inspectors of steam vessels, held at Washington, D. C., January, 1875. Washington, 1875. From Messrs. John Menshaw and F. L. Hand.

Ingeniors Foreningens Forhandlingar. 10 Vols., 1866–1875. From the Society, Stockholm, Sweden.

Report of the Director of the New York Meteorological Observatory in the Central Park, for the year ending December 31st, 1873. From the Director.

Circular of Information of the Bureau of Education, Nos. 3–6. 1875. From the Bureau of Education, Washington, D. C.

Report of the Committee appointed by the Board of Public Education to inquire into the sanitary condition of the schools of the First School District of Pennsylvania. City of Philadelphia, 1875. From Louis Wagner, Chairman of Committee.

Proceedings of the Philosophical Society of Glasgow, 1874–5. Vol. IX, No. 2. From the Society.

The Actuary also reported that in accordance with the recommendation of the Committee on Science and the Arts, the Board of Managers have awarded the Scott Legacy Premium and Medal to Job A. Davis, for the vertical feed as applied to the Davis sewing

machine; to Sholes & Gliddens for improvements in type writers; and to B. Tatham and J. M. Brittin for their safety catch for elevators.

Also the following resolutions adopted by the Board:

Resolved, That the Silver Medal of the Institute be awarded to the American Meter Co., for their Jet Photometer, in accordance with the conditional recommendation of the Judges of Class 29–15 of the 27th Exhibition.

Resolved, That the Actuary report a vacancy in the Board of Managers caused by the resignation of Prof. Geo. F. Barker from the Institute.

Dr. W. G. A. Bonwille read a paper on the use of "air as an anesthetic."

Some remarks on Dr. Bonwille's paper were made by the President and Drs. Collins and Mills.

The Secretary gave a description of the alterations recently made to the Connecting-Railway bridge, which was illustrated by a number of pictures projected on the screen.

There were also presented and described Heyl's wire book-stitching machine; Hubert's patent roofing; Spinney's patent fuel, and J. C. Bryan's lightning rods, weather vanes, etc.

Mr. Coleman Sellers offered the following preambles and resolution, which were unanimously adopted:

WHEREAS, The Franklin Institute learns that a steam street car has been built by the Baldwin Locomotive Works, and will, in a few days, be ready for trial, and that the Baldwin Locomotive Works has applied to Councils for permission to try the same on some of the street railways west of the Schuylkill; and,

WHEREAS, In the opinion of the Franklin Institute, it is of importance, not only to the manufacturing interests of Philadelphia, but to the community at large, that proper encouragement be extended to an experiment looking to the substitution of a more desirable motor than horse power for the propulsion of our street cars; therefore

Resolved, That this Institute respectfully request Councils to grant the permission applied for, under such restrictions as they may deem necessary, and that copies of these preambles and resolution be presented to to the Select and Common Councils of the City of Philadelphia at their meeting to-morrow afternoon.

The following preamble and resolutions were offered by Mr. Hector Orr, and unanimously adopted:

WHEREAS, To the array of our departed members for this year, we must now add the name of Horace Binney, who continuously

through three generations in Philadelphia has stood as our foremost citizen for many years. Therefore be it

Resolved, That we respectfully here express our appreciation of his worth as a citizen and legislator, and a hearty, though unobtrusive friend of the Franklin Institute; who bore his high faculties without pretension and never misapplied them; whose counsels are a legacy more valuable than gold, and whose example is better than both.

Resolved, That these proceedings be communicated to the family of Mr. Binney and be engrossed in full on our minutes.

Mr. Washington Jones called attention to the notice of a vacancy in the Board of Managers and nominated Mr. Chas. H. Cramp for the position.

On motion, the Institute went into an election, and the Chair appointed Messrs. Coleman Sellers and Chas. S. Close tellers.

The tellers reported more than a quorum voting for Mr. Cramp, and none against him, whereupon, Mr. Chas. H. Cramp was declared elected a member of the Board of Managers, to fill the unexpired term of Prof. Geo. F. Barker.

Mr. W. B. LeVan presented the following, which was adopted:

Resolved, That the Committee on Publication of the JOURNAL OF THE FRANKLIN INSTITUTE be requested to consider the propriety of inserting in each number, on the first page, the following: NOTE.—The Franklin Institute is not responsible as a body for the opinions advanced in its publications.

On motion the meeting adjourned.

J. B. KNIGHT, *Secretary*.

Alterations to the Connecting Railway Bridge and its Foundations.—At the stated meeting of the Institute in November, the secretary gave the following account of these alterations, illustrating them with several views, projected on the screen.

This bridge, which spans the Schuylkill river in the city of Philadelphia, a short distance above Girard Avenue, was opened to travel in 1867. It is of iron, of the Pratt truss system, originally 265 feet in length, carrying the track upon its upper chord. The approaches are of masonry, and consist of a series of semicircular arches of 60 feet span, supported on piers of varying height, those forming the abutments, and carrying the iron superstructure, being 42 feet high, and reaching 10 feet below the surface of the water, where they rest on foundations built of timber crib work, filled in with broken stones and cement.

On attempting to remove the centres on which the arches were constructed, and before the iron span was put in place, it was found that they would not stay up, but thrust out at the haunches. The iron span was then put in, with the hope that its weight would resist the thrust of the arches, and which it did do in a measure, but the masonry still moved, and to such an extent that it pressed against the lower chord of the bridge, and buckled it up in the end panels.

An arch of cast iron was then put in the bridge to counteract the thrust from the masonry arches, and this not proving sufficient, a second or upper arch was put in. These were not attached to the bridge, except to stiffen and keep them in place. In this condition it came into the possession of the Pennsylvania Railroad at the time of leasing the New Jersey Railroads.

In 1872, Mr. Joseph M. Wilson, Engineer of Bridges and Buildings, Pennsylvania Railroad, was requested to make an examination of, and report on this bridge, which he did, and afterwards took charge of it.

It was found that with the weight of the iron span, and the resistance of the iron arches, the masonry was theoretically stable, yet was slowly but surely disintegrating under the varying resistance due to the expansion and contraction of the iron arches from changes of temperature.

A variety of methods for remedying the difficulty suggested themselves, but the only one considered feasible was to go down to the bed rock of the river in front of the piers supporting the iron span, and build up additional masonry, connecting it to the old, and shorten the superstructure by one panel at each end, change the end posts, and remove the iron arches.

To do this, the pier was surrounded with a 16 sided coffer dam, 66 feet in diameter in the clear, on top, built of 12 inches square timber, placed horizontally, and having an inner and an outer shell, the space between being 6 feet at the top and 10 feet at the bottom, and which was filled with loamy gravel puddle.

The rip rap around the abutment piers in the way of the proposed dam, having been dredged out, and the bottom cleaned as well as practicable by divers, the coffer dam was first framed and put together on shore, the bottom edge, cut to fit the profile of the rock bed of the river, and then taken to pieces, and erected in place.

Short vertical pieces of plank, sharpened wedge-shape at their lower ends, were then nailed to the outside of each face of the dam, being

well driven down to the rock to make a tight fit. The spaces between the rock and timber were then calked with oakum by divers, and filled in between with cement, after which the puddle was put in place.

To remove the leakage of the coffer dam, pumps were provided, with a capacity of 4000 gallons per minute, but only about one-tenth of this was required, as the actual leakage as nearly as could be ascertained, did not exceed 400 gallons per minute. The remainder of the rip rap, in the interior of the dam, was then removed, and the rock reached at a depth of about 32 feet at the east, and 37 feet at the west pier, at the lowest point.

The rock was carefully cleaned off, and the new masonry built from it, being about 15 feet additional; the old pier being 12 feet at the spring of the arch, 15 feet at the base, and 17 feet at top of crib foundation.

The iron arches were then taken out, the bridge shortened about 13 feet at each end, the end posts being moved in one panel, and the entire work is now completed, with the exception of a small portion of the railing on top, all having been done without any interruption to travel, and being in every way an entire success.

The work was in charge of Mr. Wilson, as stated, but was executed under the immediate superintendence of Mr. Stacy B. Opdyke, Jr., Assistant Engineer, Pennsylvania Railroad.

The contractor for the coffer dams was Mr. Jonathan Powell; for the masonry, Messrs. Smith & McGaw; and for the changes in the iron superstructure, the Keystone Bridge Company, by whom it was originally built, from designs by J. H. Linville, Civil Engineer; but it is proper to state, in this connection that the original errors in the construction were entirely connected with the masonry, which did not come under Mr. Linville's charge. K.

The Market Street Bridge.—The superstructure of the Market Street Bridge over the Schuylkill, was entirely destroyed by fire on the afternoon of Saturday, November 20th. The bridge was originally built in the year 1800, by a private company, and replaced a floating bridge of previous existence. It became the property of he city of Philadelphia (prior to the consolidation) in the year 1840; and the superstructure was entirely reconstructed in 1850. The abutments and piers are as they were first built, and are said to have had a foundation upon the solid rock; that of the western abutment

being 41 feet below the level of ordinary high water mark. The three spans are 150,—194,—150 feet, clear of abutments and piers.

The superstructure which has been burned, consisted of three spans of timber framing, composed of arches, combined with "Burr" truss work, and was built with every care to make it substantial and *permanent;* and it was subsequently further strengthened by the Pennsylvania Railroad Company, when they acquired the privilege of using the "city track;" until it was one of the strongest bridges in the country. The whole was covered by a wooden roof, with tin outer covering, forming altogether an immense mass of dry wood work.

An averment has been made by a person who purported to be an eye witness, that exactly twenty-seven minutes elapsed after the flame appeared (which was simultaneous to the discovery or alarm); when the first span fell, the second followed instantly, and the third at an interval of four minutes.

The traffic upon this bridge had quite surpassed its capacity, and the necessity of enlargement and reconstruction had become apparent, and the opportunity now given to accomplish this purpose, is in some way a ground of reconciliation for the loss. It is to be hoped that this opportunity will be suitably availed of, and that the new structure will combine excellence with architectural effect; a combination not completely attained in some of the bridges over the Schuylkill.

Bibliographical Notice.

THE NEW METHOD OF GRAPHICAL STATICS. By A. Jay Du Bois, C. E., Ph. D. Reprinted from *Van Nostrand's Engineering Magazine.* New York, 1875. D. Van Nostrand.

While it is not quite correct to call this method a new one—the students of the Ecole Polytechnique of twenty years since were made conversant with most, if not all, the applications set forth—we presume it will prove really novel to general students and readers in applied mathematics, and especially to many practical engineers. Any process which avoids, or eliminates, or corrects errors of computation, is of great importance; and this one, which accomplishes all these and besides gives a general solution to problems, when figures only offer particular ones; should be made familiar and ready of application. The printing of figures in the text, in place of in separate plates, would have added much to the convenience of those requiring the book for reference, but this deficiency will be overlooked in its usefulness; and in its shape of a separate treatise, the work should form one of the books of an engineer's library.

Civil and Mechanical Engineering.

THE PRODUCTION OF TRULY CYLINDRIC SURFACES FOR CALENDER OR OTHER ROLLS.*

All mechanics who have had many years' experience in the workshop, have learned that the most accurate result of turning fails to give either parallelism or concentricity to a cylinder. Only a relative perfection of the lathe in all its parts, an almost accidental homogeneity of the material upon which the turning is done, a fortunate endurance of the tool used on the work, and much skill of the workman allows even an approximate cylinder to be made. The admitted conclusion of the mechanic is that following the turning, and after as good work has been done as will proceed from average lathes, tools and workmen, the rolls must be finished by a grinding process. The method of trueing the surface of a cylinder by grinding wheels (stone or emery) mounted on a carriage traveling on the ways of a lathe, in which lathe the roll is hung, either on centers or on its own bearings, is well known, but this process is so embarrassed by the imperfections of the lathe ways (either original or in wear) by the spring of the roll away from the grinding wheel, and by the necessity of great accuracy in setting the roll parallel with the ways, that the production of a perfect roll becomes almost impossible. After attaining a degree of perfection in this way, the workman has found the grinding of two rolls together, with a slight vibratory motion to one of them, to be the best way to correct the errors of diameter, and straighten their faces. And after all, much labor, skill and care has failed to satisfy the critical workman, and only produced calender rolls for paper machines that have sufficed for, rather than answered the requirements.

* A previous description of this method, with a cut of the machine, will be found in Vol. lxi (3d series), page 392, but as it was not thought by Mr. Poole himself (the compiler of the description), to be sufficiently clear and definite, the present paper has been prepared. It is proper to add, that the author of the present paper was not aware of the existence of the previous one until after the completion of his article, ready for the press; but a comparison of the two papers has led him to conclude that the second one may prove instructive.

There was shown at the recent exhibition of the Franklin Institute, by J. Morton Poole & Co., of Wilmington, Delaware, a paper calender, having eleven rolls. The rolls were 7 feet in length, measured on their true faces, the top roll being 12 inches, followed by eight rolls of 7 inches, one of 12 inches, and a bottom roll of 15 inches diameter. These rolls were, all of them, as far as possible callipering and examination would detect, *perfectly* parallel and concentric, and would bear the exacting test of the perfect visual contact when interchanged.

The machinery for production and finishing these rolls being protected by patents held by Mr. Poole, he has willingly exhibited it, and a brief description of the principle involved, and special apparatus employed, will be of undoubted interest to the readers of the JOURNAL.

Any person wishing to find if a shaft or roll is round or is parallel, would try it with a pair of callipers. This is *all* that Mr. Poole has done. Only that he has mounted at each toe of the *callipers* an emery (corundum) wheel, and these wheels grind the spot they touch, to the desired uniform calliper. The roll being mounted in a lathe, the *calliper* wheels (one on each *side*) are passed down it *on the line* of the centre (or very close to this line) whilst it revolves.

Any machinist will see that if the line of the centre of the roll in this supposed case is exactly in the plane of the path of the axis of the grinding wheels, the result, after all requisite grinding is done, must be a perfectly callipered roll (and this is also true if the line of the centre of the roll is parallel to, above or below, the plane of the path of the axes of the grinding wheels.) But then this may not, therefore, be a round one. A cardioid or heart shape cam, or an eccentric will calliper perfectly, and yet not fulfill the requirement of cylindric perfection. Now, if we consider the *callipers* to hang freely, it is evident that if they are grinding an eccentric or cardioid shape, they will oscillate to follow the eccentricities. If, therefore, the *callipers* are held from swinging by friction of sufficient amount to make one of the two wheels do all, or most of the work, the high place of the eccentric or heart will be reduced first on one side and then on the other, and when a reduction is once provided for, it is only a question of time when the object will become *perfectly* round.

The great interest which attaches to Mr. Poole's system of grinding is in the close approximation to mathematical accuracy resulting from it, in the production of *original* cylinders, cylinders which in no

respect follow or repeat inaccuracies of their own, or even of the machine used in finishing them, and so nearly fill the requirements of exactness that eight or ten can be selected from a thousand, and piled into a set ready for use. It is not essential that the finishing (grinding) lathe shall pretend to much accuracy in construction, for it is incomplete unless the roll to be ground is in place. *The roll itself forms part of the machine*, and its axis of rotation is the real guide for the path of the callipering grinding wheels.

To make this condition better understood, let it be conceived that at any place the callipering wheels are stopped from traversing along the ways of the lathe bed, and operate upon a portion of the roll that is decidedly eccentric from fault in turning. At this point of the roll, the grinding wheels acting as callipers, will vibrate back and forth (crosswise to the roll), moved by the eccentricity; but from the resistance to this motion given by clamping them, they will cut hardest on the high sides, and the force required to vibrate the callipers will in time wear down the eccentricity, and a true circle be the result. What has thus occurred at one point on the roll surface, will be repeated by traversing the grinding wheel for its entire length, and the finished roll becomes the mere extension of the true circle into a cylinder. Thus the grinding lathe *originates* an absolute cylindrical form without the aid of straight-edge or guiding former-bar.

The condition of this accurate grinding was stated to be the coincidence or parallelism of the axis of the roll with the plane of the path of the axes of the grinding wheels. If the roll is placed much out of this plane, it will be noticed that the callipers will only measure the diameter at the point where it coincides with the plane, and that anywhere else they measure above or below the centre. If the point of coincidence of diameter be the middle of the roll, the shape resulting is dice-box form (a hyperboloid of revolution) and in fact this very shape is produced sometimes intentionally, as in the case of chilled rolls for sheet iron, which require to be a little hollow in the middle to compensate for the greater expansion of that part by the heat, when rolling iron. But if the roll so nearly coincides, that the variation of the line of the axis of the roll with the plane of the path of the axes of the wheels (or a plane near to it, but parallel with it), bears but a small proportion to the diameter of the roll, the error in true cylin-

drical form becomes exceedingly small.* If a roll 10 inches in diameter is assumed, and if the grinding wheels be taken to be 8 inches in diameter; and if the roll be placed in the grinding machine 1-10th an inch out of the proper position, (supposing in this case the middle of the length of the roll to be in the right plane and the ends 1-20th an inch up and down) the diameter at the end of the roll will exceed that of the middle by 1-6480th of an inch.

Now it is perfectly feasible to set a 10-inch roll within 1-50th of an inch, and the inequalities of the ways of a bed arising from wear ought to be kept within this limit, and if 8-inch grinding wheels are supposed, the practical accuracy following this setting would be within 1-162000th of an inch. The sag of a roll (for they are ground in horizontal position) from its weight alone is an estimatable quantity, is so small in rolls of ordinary proportions that 1-2000000th of an inch would include the error in parallelism proceeding from depression from proper plane in the centre, for a roll 8 feet in length.

The effect upon the trueness of the cylinder of setting the roll in the grinding machine, out of the line of the ways or path of the callipering wheels, but in the proper plane, is nothing whatever, within large limits of deviation. After the roll is rounded by grinding, it is obvious that it makes no difference how the callipers move, only provided the points of contact with the cylinder be on the diametrical lines; and even when rounding up with the callipers held by friction from freely placing themselves, the oscillatory movement of the callipers continues so long as any eccentricity exists, after which the calliper movement becomes steady, and the friction resistance transfers the grinding work mainly to one wheel, when the traverse is in one direction and to the other on the return. It is only necessary that the friction nip should not relieve one wheel entirely, and it is of course best, after the roll is truely round (a condition easily detected by the marks on the face left by the wheels) to complete the finish of the surface with free *callipers*.

The small errors indicated as possible to this system of grinding

* The error resulting from want of parallelism of axis of roll with the plane of the path of callipering wheels is, (neglecting the square of the error as inconsiderable) at any part above or below the normal plane =

$$\frac{\text{Twice the square of } \left\{\begin{array}{l}\text{elevation or depression, multiplied by diameter of the roll} \\ \text{divided by the sum of diameters of roll and one wheel}\end{array}\right\}}{\text{divided by the diameter of the roll.}}$$

with but a minimum of care in setting can be nearly eradicated by excellence in workmanship, and Mr. Poole does actually work below the limits here stated.* Admitting an error of a 50000th part of an inch to exist, and to be distributed (by a uniform deviation out of plane) into the surface so as to give the hyperboloid before spoken of; admitting this, the contact of a set of rolls would still be perfect, for the error is far within the elasticity of the material of the roll, so that a set of nine rolls thus ground, would have line bearings on each other of apparent perfection.

In fact, the lower roll of a set in a calender cannot be ground entirely by this system; for it has to carry the weight of the entire set, and of itself, and is depressed to a catenary form. The material of these rolls under their own weight can be considered as perfectly elastic and the pressure will then be that of a fluid of uniform depth upon the *string* support. It has, therefore, been found necessary to produce a barrel shape roll for the bottom one. The amount of enlargement in the central diameter for a six feet by fourteen inch roll is stated by Mr. Poole to be about 1-150th an inch. This roll, therefore, is first trued up round and parallel by the described process, and then is barrel shaped by the usual one of a "*former-bar*" guide to oscillate one of the *calliper* legs. This former is made with perfect accuracy, as compared to one planed up, by using a truely ground cylinder of proper length, which is laid parallel to the roll with the greatest care, and is *sprung*, by being held at both ends and forced out by a sheet of paper thickness, in the middle of its length. The accurate setting of this "*former-bar*" is ensured, if the roll is first ground parallel, by the length of the cut of the grinding wheel at each end of the roll: an indication that is measurable, in this case to a millionth of an inch. The curve derived from this distortion of the *former-bar* is not ex-

* While it is so easy for a tolerably skillful workman to set the axis of the roll in parallelism with the plane of grinding wheels, it is possible to arrange the machine so that even this care of setting may not be demanded. If, in place of hanging the grinding carriage, at both ends, from the horns of the traveling carriage, it should be hung from one end only, while the other end depends from an arm which runs or passes over the roll, and rides upon it, by a wheel (or slide) the grinding will then be done *altogether* independent of the ways of the lathe. This arrangement will therefore compensate of itself for all errors of setting, or wear or inaccuracy of ways. In such case the riding wheel (when one is used) must necessarily be very true for the attainment of absolute perfection.

actly that desired, but it approximates to it, and by the condition of nearly perfect elasticity for exceedingly small movement, as has been before stated, the two curves coincide to all needful accuracy.

The grinding machines to operate on this principle present, as made by Mr. Poole, some peculiarities of construction worthy of note. Taking for description; the finishing machine for grinding callender rolls of from 6 inches to 16 inches diameter, and 5 feet to 8 feet in length of face. Such a machine consists primarily of a massive bed (and trough for water) much like that for a lathe of 48″ swing. Upon this bed are mounted—a driving head—two housings to take the roll necks and a carriage to travel between the housings and carry the grinding wheels. The driving head is of course out of all proportion with that needed for a lathe of similar dimension, and in fact the spindle is but 3 to 4 inches diameter, and the power is applied by a large overhung pulley without gears. This pulley is some 5 feet in diameter by 5 inches face, and is driven at about 40 revolutions per minute. [Belt power only answers to give that uniformity of motion to the roll which will produce a smoothly marked surface, for the best of cut gears leave their impression on the finished roll.] Under the spindle is placed a reversing screw gear for actuating the carriage. The mechanic will need no description of this attachment, only to say that the feed is about 3-16th an inch, and that the screw is properly shielded from drippings. The housings with their adjustments for bearings for the necks, also do not call for description to be understood by the practical man. The carriage, with what *we have called the callipers* need a more full explanation. The carriage is like that upon any lathe bed, up to the bottom of the tool post slides, but it has four posts or horns cast upon and forming part of it at the front and back corners. These posts are perhaps 12 inches apart, along the carriages, and three feet apart across it, they are T shape with the flat of the T's towards each other, and they are not capped but the top ends are open. They are about 18 inches high. Fitted between the posts, a loose sliding fit, is placed a substantial double ended cross slide rest, which hangs, by links or knife edges, from the upper end of the posts or horns, and is free to swing from side to side across the lathe. Upon this cross slide rest at either end is mounted like tool posts, two boxes which contain the grinding wheels. Everything about this part is solid and substantial, and this arrange-

ment forms the *calliper* we have so often referred to. The *calliper* will thus be seen to be applied from below upwards—the friction which prevents oscillation is obtained by a set screw in one horn which bears on a spring washer and thus effects the *nip*.

The grinding wheels used are a special make, none having been found on sale that would fill the demand of durability so as not to wear appreciably in one travel of the carriage, and also of capability to be run with water. It being, as is well known to all grinders, impossible to get true work from a stone unless water is used freely to preserve the temperature. Corundum has proved most suitable, and the wheel-making part of Mr. Poole's establishment is by no means the least important, either in expenditure or appliances. The wheels are, when new, about 9 inches in diameter by 1½ inches thick; they are mounted on heavy spindles with conical bearings and have pulleys to drive them, on both sides of the wheels, about 4 inches diameter by 2 inches wide. Great care is taken to balance each part of the body in rotation, separately and together, so as to get out the least jump of the grinding wheel.

The grinding wheels run with about the circumferential speed of a mile per minute. The actual reduction of a cylinder due to one pass or traverse of a pair of grinding wheels, as determined by many experiments, does not vary much from 1-20000th of an inch (= 1-40000th at each side). They are driven by *two* overhead drums, one below the other, the upper one 18 inches diameter, and the lower one 15 inches in diameter. These drums are 8 or 9 feet in length so that the belts can traverse up and down with the carriage. They are made from sheet tin, like some of the cylinders of a paper machine, and are carefully balanced at every point of their length so as to be in equilibrium of rotation. The disposition of each belt is as follows: the slack side of the belt passes down from the top drum, under the spindle pulley of wheel on front of machine, then being drawn up over the lower drum, it is passed down from the lower drum under the spindle pulley of wheel at back of machine, and finally it is a second time drawn up over the top drum to the place of beginning. The tension of a vertical belt depends upon the elasticity either of the belt (or of the shafting) and it is found necessary to drive the two drums in such way, that the surface speed of the top drum shall be just enough less than that of lower drum, as will com-

pensate for the stretch of the belt and avoid throwing all the *slackness* into the down side of the belt from the top drum, in order to ensure proper adhesion to the pulley of the first spindle. By this double loop arrangement of belts, the work is accomplished by two belts in place of four, and the contact of the belt with the spindle pulley is made 180° without using a cross belt. A cross belt is undesirable for a traveling one.

It will be noticed, that the tension of the belts tend to lift the carriage off its links and knife edges, but the weight of the carriage, with the wheels, spindles, etc., is so large as to resist this strain, and also to avoid any unsteadiness therefrom.

The arrangement of counter-shafting for driving the machine and the drums does not call for description. A copious supply of water is fed upon the roll while the grinding proceeds; this water is pumped up to a tank by a pump attached to the machine, and as the same water is used over and over, the fine corundum in suspension adds materially to the cutting effect of the wheels.

Calender rolls of greatest excellence are an American product, and depend upon our grade of gun iron produced from charcoal pig of Connecticut origin for the best, but it is probable that the product of a Siemens–Martien furnace, or possibly Bessemer material will eventually allow other iron to be used. They (the calender rolls) are now produced chilled to moderate hardness (the superlatively hard chill is blowy) with *absolute perfection*, without a pin-hole or blemish on an entire roll surface.

In turning of these rolls, exceedingly strong lathes of ordinary form are used to cut off the rising head, and true up the necks, and they are faced up in the roll lathe (of the rolling mill), which differs materially from the machinist's slide rest lathe. Both the necking and roll lathes of Mr. Poole present many features of specific excellence and novelty, but the length of this paper will not permit more than this allusion to them, except that it is proper to mention that the tool used in the roll lathe in cutting chilled iron is a flat bar of planed steel about 3½ inches wide by 1¼ inches thick, and in lengths of from four to ten inches. The cutting edge is formed on four corners of two sides in this way: a groove a half-inch in width by one-eighth of an inch deep, is planed along the side in the middle of the thickness, and the edge (thus relieved in the centre), is ground in an ordinary parallel grinding lathe by a six-inch wheel, to the

shape or concavity of the grinding wheel. This procedure gives a cutting edge of 78°, and has been found by Mr. Poole to answer perfectly, when used in the roll lathe method of crowding up to the cut. It is however admitted that no steel is good enough, or can be made hard enough, to be so perfectly satisfactory that nothing better could be wished.

Before commencing to grind the surface of a roll, it is indispensible that the necks shall be true and round. Exact parallelism is not requisite, but the first step in roll grinding is to grind the necks on dead centres, to positive roundness. Except this is done, the *calliper* grinding of the bodies only reproduces all the eccentricities in the necks. When this precaution is neglected, the rolls will fail to drive each other without being geared together. The test of accuracy, or rather of freedom from eccentricity, is the absence from tremor when the "stack" of rolls is running. When perfect, not the slightest vibration can be felt.

It has been stated, that the action of the grinding wheels was determined to be 1-20000th of an inch for both wheels (1-40000th each). With this rate of grinding, a chilled roll of American hardness, 12 inches in diameter and 72 inches face, turned in Mr. Poole's roll lathes, with the bearings ground beforehand on centres, can be finished in seven and a half hours. To effect this, the turning must have been exceedingly accurate, and no error of callipering in the lathe, or of eccentricity proceeding from inequality of hardness of chilled surface, (or more generally from spring of the roll in cooling, which may demand a strong cut on one side, and a very light cut on the other) greater than 1-500th or 1-600th of an inch must exist prior to the grinding.

*An idea of the minuteness of the error which will prevent continuous contact of any two rolls can be entertained by referring again to the work of one grinding wheel, on one pass or traverse, equaling 1-40000th of an inch. Arrest one of these wheels anywhere in the length of a roll, and prevent it from taking its 40000th of an inch from the cylinder, and the defect becomes manifest when two

* The remarks in this paragraph are Mr. Poole's own comments, and are the undoubted result of practical test within limits of observation. The most perfect of ground polished or burnished iron surface fail to satisfy a microscope of quite low degree. The test for light was not made in a dark room, the reflection on the cylindrical surfaces brought in interferences of much complication, and the high elasticity of iron under small loads or in almost differential compression, would limit all these tests to the usual condition of *approximate accuracy*.

rolls are placed in contact, not by passages of light, but by the break in the continuity of the burnished line made by sliding one roll upon the other. When two cylinders of iron are placed together, it is just possible to detect by the eye an opening of 1-4000th part of an inch, and this minute opening separates the light into its prismatic colors. The linear contact test, therefore, becomes ten times as perfect as the visual one.

As an example of the degree of accuracy attained by this new method of grinding, the experience of Mr. Poole's machine in Wurtemburg can be cited. The government of Wurtemburg is of itself the proprietor and operator of the larger manufacturing industries (which are generally carried on by companies elsewhere), such as mining, iron and metal works, machine shops, paper making, etc., etc., and became a purchaser of Mr. Poole's patents for the Kingdom. Among the stipulations was one founded on the statement as to time (7½ hours) required to grind a 12″ × 72″ roll, which was made a condition of performance obligatory on Mr. Poole, under penalty of forfeiture of agreement. This was easily accomplished, however, as the Wurtemburg chilled roll for the test, from the nature of the iron, proved softer than any American one, and was turned to greater accuracy than can be reached with more intractable material, and but 3½ hours were needed to effect the desired grinding.

But a more satisfactory exhibition of the excellence of the new process was afforded when a roll previously finished in the same workshop, was *tested* in the new grinding machine. This roll had been an especial effort, having been finished for the Vienna Exhibition, ground and polished to the highest brilliancy, and had *come back* from the exhibition with an award. It was found so tapering and generally imperfect, as to require and occupy two days' grinding to bring it to cylindrical form.

In 1868, when this method of grinding rolls was first introduced, there is said to have existed in all the paper mills of the United States but two "*stacks*" of chilled rolls; or, at least, Mr. Poole avers that he only knows of that number. These stacks were five rolls high, and the rolls were short, 48-in. and 62-in. faces, respectively. Chilled rolls were, however, commonly in use at that time, as super-calenders in writing paper mills—say from 24 to 30-in. face. No maker of paper machinery had ventured to make chilled rolls, for machine calenders of 72 to 84-in. face, which has been

demanded to meet the requirements of width, of the common Fourdeinier machines. The stack shown at the exhibition of the Franklin Institute, was 11 rolls high, with 84-in. face, and is not an uncommon stack at this time. The great superiority of calendered paper, and of paper calendered by perfect rolls; in freedom from buckles; mottled, dead and bright places; and in parallelism of the sheet, has led to a rapid increase of calenders, both in this country and abroad. And an actual improvement in the manufacture of paper has been effected.

The several results can be summed up. The accomplishment of mechanical accuracy on philosophical and theoretical bases; the construction of machinery by economical and thoroughly practical process; and the consequent advancement of one of the greatest industries of civilization, *the manufacture of* PAPER. B.

AIR BAGS FOR RAISING VESSELS.*

Air being seven hundred times lighter than water, a bag made of a very light water-tight material, when filled with air, affords easy and powerful means wherewith to raise sunken bodies. Air bags are convenient for stowage and transport, because when not in use they occupy very little space, while at the same time when wanted they can be expanded into large dimensions. The greater the weight of body to be lifted by means of air bags, the larger, of course, must be their displacement, and as the bags are generally manufactured of certain fixed dimensions, the weight of the submerged body must determine the number of air bags to be applied.

The first to suggest the use of air bags for this purpose was Professor St. Claire, of the University of Edinburgh, who proposed them in the year 1785. But as the india-rubber industry was then but barely developed, air bags could not then have been manufactured of that material so as to be of practical use. So recently as in 1864, air bags were for the first time practically applied by Bauer for raising the steamer Louis, which sank in the Lake of Boden. But on that occasion, owing to the bags being pear-shaped, they could not sustain the pressure, and gave way. The idea of using the air bags in Russia originated with M. J. Alexandrovsky, and the system was adopted in 1865, at the time when the turret ironclad Smertch foun-

* From *Engineering*, London, October 29th, 1875.

dered in the Baltic sea. Mr. Alexandrovsky was supported by Admiral Popoff, of the Russian Imperial Navy, who assisted him greatly in bringing his invention into practice, carrying out experiments so as to render the air bag system what it now is, namely, a very valuable means of raising ships, etc., and which has already rendered good service to the government and commerce of Russia on several occasions.

The air bags adopted in the Russian navy when inflated are of cylindrical form, measuring 12 ft. in diameter, and 20 ft. in length. The useful part of their displacement or their lifting power in practice averages 60 tons. Air bags measuring 15 ft. in diameter and 20 ft. long, will lift about 100 tons, and cost, acording to the number required, from 375*l.* to 350*l.* each in St. Petersburg. The skin of the bags, of the sizes mentioned, is composed of three layers of the thickest canvas, saturated with india-rubber. Between each of the canvas layers is a sheet of india-rubber. The two inner layers of canvas are made up of strips sewn together along their edges, and laid in the direction of the length of the bag, whilst the third or external layer is made of canvas strips surrounding the bag circumferentially. The strips of this last layer thus cross those of the layers underneath it. This arrangement of the skin layers secures in the bags the required amount of resistance and durability. The external surface of the bag is fitted with special straps through which it is surrounded with a close, strong rope net, which increases the strength of the skin, and a layer of matting is interposed between the skin and the rope net.

In order to distribute over the whole surface of the bag, the strain to which it is subjected when lifting heavy bodies, the bag is enveloped in a series of longitudinal and transverse, or circular hempen cables. To the lower ones iron eyes are fastened, which afford means to connect the chains securing the bag to the object to be raised. When necessary, an oak beam 12 ft. long and 14 in. or 16 in. square is attached to the cables which surround the bag transversely; and to this beam the connecting chains are made fast. Each of the air bags is fitted with a valve, which is screwed in at the top and in the centre, together with an india-rubber hose, by means or which air is forced into the bag. At the ends of the bag, also in its upper part, are two smaller valves with tubes intended for letting the air out, and for holding the pressure gauge, which is applied for the purpose of ascertaining the amount of pressure inside.

In the interior of the bag, along its bottom, two short lengths of hose are sewn in so that they cannot move laterally. One end of each of these pipes which is open, terminates close to the end of the bag and in the interior of it, whilst the other end passes out at the opposite end of the bag at the bottom, and is fitted with a safety valve, which opens when the bag is fully inflated with air, and the pressure begins to exceed the surrounding water pressure. By means of these two safety pipes and valve the bag is secured from bursting, and the pressure of the air within it distributes itself evenly in both ends of the bag. The bottom part is fitted with a man-hole sufficiently large to admit the entrance of a man, for inspecting the interior of the bag, and for repairs.

In order to lift the sunken vessel, it is necessary first to send down divers to examine her condition, and to find the spot where it would be most convenient to pass chains or cables underneath her keel. For this last purpose the divers at first pass a thin rope underneath the bottom of the vessel, which is followed by a rope of greater thickness, attached to the first, and terminating at the other end by a chain or the cable. It sometimes happens that the power of the divers below, and that of the windlasses above, though sufficient to draw a thin rope under the vessel, are insufficient to haul a thick cable. In such cases an air bag is attached to the end of the thin rope, and this bag being inflated acquires an ascending power sufficient to carry with it a cable of any required thickness. This method was successfully adopted, when a vessel sunk in a depth of 15 fathoms was being raised, and when the power of 200 men with windlasses proved to be insufficient to draw the chain underneath the vessel.

When several chains have been drawn underneath the bottom of the ship, the air bags are attached to the ends of each of them, as near to the bottom of the ship as possible. The bags being inflated by means of air pumps cause the ship to rise. Before pumping air into the bags, care is taken to connect together all the chains which surround the hull of the vessel in a transverse direction, so as to form a longitudinal continuous belt, which uniting all the chains into one system, prevents the end pairs of air bags sliding off from beneath the extremities of the vessel. As the ship rises, the surrounding water pressure decreases, and the excess of air passes out from the bags through the safety valves, with which each air bag is provided.

This method of raising vessels and other sunken bodies by means of air bags is of very great importance, especially when the work has to be performed in the open sea, because, in rough weather the bags without any air in them can be left under water with buoys to mark their position, until the weather becomes more favorable and the sea calm.

When lifting vessels from great depths, the work must not be accomplished by one process; that is, the whole number of air bags required to complete the work should not be applied to the ship at one time. This precaution is necessary, because, when the vessel, tied up with chains, and provided with the full number of air bags, ascends rapidly from a great depth, and gets to the surface of the water, it is raised, by means of its acquired momentum, higher than is consistent with equilibrium at the surface. Eventually, after attaining an unbalanced position, the whole is submerged again. This arises from the circumstance that from the moment the ship leaves the bottom of the sea, and during her ascent, the surrounding water pressure is gradually decreasing, and the air from the bags is passing out. Therefore, at the time when the ship reached the surface of the water, the bags would not possess the amount of lifting power necessary to keep her on the surface. Accordingly, the ship would return to the bottom. To prevent this, one, two, three, and in some cases four bags (according to the size of the vessel), out of the whole number required are fastened to the chains which surround the vessel, not close to her, but at a depth of some two or three fathoms below the surface of the water. By such distribution of lifting power, the vessel, having separated herself from the bottom of the sea, would ascend until the upper bags reached the surface of the water. The whole system is then towed to another place, where the water is shallower than where the wreck occurred. The air bags which reached the surface of the water at the first operation, are again submerged, and are tied to the chains several fathoms lower down. By repeating these operations several times, according to circumstances, the ship will be brought to the surface gradually, and by easy stages with the certainty of success.

These precautions are also necessary in those cases when, as it sometimes happens, the sunken ship, after having separated herself from the bottom of the sea, would be raised not horizontally, but with one end higher than the other. By having several air bags, out

of the whole number, attached at a depth of a few fathoms below the surface, it insures that the rise of the higher end of the vessl will be limited only to the height equal to those few fathoms, and the chains with the air bags surrounding the ship cannot slide from underneath her. This method of working affords a sure means of ascertaining whether there is any necessity to increase or decrease the lifting power at either extremity of the vessel.

In the year 1869, a merchant schooner foundered in the Baltic, and in order to save her heavy cargo, consisting of pig iron, air bags were made use of. This case proved how powerful the air bags were, because, when the upper part of the vessel was surrounded by the longitudinal belt of chains with the air bags attached to it, her deck, with the whole of the masts, spars and fittings, together with the upper strakes of her sides, were torn away by the power exerted by the bags, and were carried up to the surface, the breakage occurring just along the line where the bags were applied. After having thus opened the hold, her cargo, and afterwards the vessel herself, were lifted up easily and successfully. The next useful work performed with the air bags was the lifting, in 1870, of the gunboat Metch, which sank in the roads of Tranzund, in a depth of 21 feet.

Soon after this, in the same year, the steamer Ilmen, which had foundered near Viborg, was raised. The work was completed in the short space of ten days, thus proving the simplicity and ease with which the air bag system can be applied.

In the same year the ironclad Sevastopol was lifted for repairs by means of bags, so that access was obtained to the wooden planking separating the armor from the copper sheathing. The edges were caulked, and the planks replaced by new ones. By these means, in five days only, and with very little expense, the leakage from which the frigate suffered in 1869–70, and also the destruction of the lower armor plates, due to the action of copper sheathing, were successfully stopped. Had not the bags been employed, it would have been necessary to place the frigate in dock, and as the docks at Kronstadt, at that time, were not so deep as they are now, this work would have necessitated the removal of her armor—a heavy and very costly job—or the frigate could not have been commissioned until the new dock was completed. During the same year, also, air bags were used for raising the stern of the ironclad frigate Minin. With the help of two barges and four air bags, the frigate

was successfully conveyed over the Neva bar to Kronstadt. In 1870, the imperial yacht Standart being raised by means of eight air bags, was conveyed in a similar manner over the Neva bar. In this work, also, the use of air bags greatly reduced the expense, and saved much time. In the same year, the air bags were utilized for lifting up the stern of the ironclad Prince Pojarsky, when she was brought through the gate of Petrovsky Kronstadt Dock, where the ship had her armor plates put on, and whence she could not be taken out without taking these plates off again.

In 1872, in Biorke-Zund, a vessel sank in 90 feet of water. It was intended to lift her by means of barges, but this attempt failed, after much time and money had been spent. On the attempt being made with air bags, the work was successfully accomplished, notwithstanding that this vessel, owing to her cylindrical form, her comparatively small size, and her very heavy weight, proved to be very difficult to raise. The lifting of this vessel thus from the bottom of the sea, showed that the work could only have been successfully carried out by means of air bags.

The system afforded no less important aid in 1873, in the Black Sea, where the necessity occurred for changing the pitch of the propelling screws of the Popoffka Novgorod. The form of this ship did not allow her to be taken upon any slipways existing at that time. This work required but three bags, and by means of them the stern was lifted to a height of 5 feet.

Last year, a merchant steamer, the Dornkat, which foundered in 11 fathoms of water, near London Lights, in the Baltic, was lifted by means of eight air bags. Notwithstanding that at the beginning of the work the steamer was surrounded on all sides by the ground at the bottom of the sea, and was buried in it, and that the work was carried out in an open sea, the steamer was successfully raised.

In the autumn of last year, by means of the air bags, the stern of the Popoffka Novgorod was lifted twice for the purpose of lengthening the blades of the propelling screws, and to change their pitch. This year, air bags have been usefully applied on several occasions, and at present they render great services in the construction of the new bridge across the Neva, in St. Petersburg. In this case, they are used to keep in a vertical position the iron caissons during their erection. It will thus be seen that the air bag system is in every respect one which may be of great value to the royal and mercantile navy.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 262.]

With the vessel at the speed of 7 geographical miles per hour, and screw H revolving freely, the aggregate resistance of vessel and screw was 756 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 125 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{125\times100}{621}=\right)$ 19·81 per centum; and decreased its speed ($\sqrt{}$ 631 : $\sqrt{}$756 :: 7 : 7·6620 and 7·6620 — 7·=) 0·6620 geographical mile per hour, or $\left(\frac{0{\cdot}6620\times100}{7{\cdot}6620}=\right)$ 8·64 per centum.

From the foregoing it appears that the resistance due to screw H when revolving freely, is 25·04 per centum of the resistance of the vessel, *per se*, less than when it is held stationary with one blade vertical *below* the shaft, immediately behind the vessel's stern-post; 37·40 per centum less than when it is held stationary with one blade verticle *above* the shaft, immediately behind the stern-post; and 32·65 per centum less than when it is held stationary with one blade horizontal, square across the vessel, on one side of the stern-post, while the remaining two blades are on the opposite side at angles of 30 degrees from the perpendicular.

General conclusions.—From the results of the preceding experiments made to determine the relative resistances of the screws of steam-launch No. 4 when dragged through the water in various positions and under different conditions, the following general conclusions can be drawn:

First. All the screws experimented with continued to revolve until the vessel's speed fell below 3½ geographical miles per hour.

Second. That with the exception of the extreme case in which a two-bladed screw is employed, composed of such small fraction of the pitch that its projected area on a plane at right angles to the axis is covered or masked by the stern-post of the vessel, the two bladed screws gave much less resistance when revolving freely than when held stationary with their blades in the vertical position immediately behind the stern-post of the vessel.

Third. That even in the extreme case above excepted, and which never occurs in practice, the resistance of the two-bladed screw when held stationary with its blades in the vertical position immediately behind the stern-post of the vessel, was only 2 per centum less than when revolving freely. And that this slightly less resistance was due to the fact that, because it was masked by the stern-post, owing to the extremely small fraction of the pitch of which it was composed, it made, when revolving freely, fewer revolutions per minute than it would have made if composed of a larger fraction of the pitch, and consequently had to be dragged bodily through the water at a higher speed.

Fourth. That the resistance of the two-bladed screws when their blades were held stationary in the vertical position immediately behind the vessel's stern-post, was much less, for all the fractions of pitch employed, than when they were held stationary in the horizontal position square across the vessel. And that this difference of the resistance in the two positions became less and less as the screws were composed of greater and greater fractions of the pitch, all other things being the same.

Fifth. That in the case of screws otherwise identical, except that the surface in the one was divided into two blades, while in the other it was divided into four blades equispaced around the axis, the two-bladed screw when held stationary with its blades in the vertical position immediately behind the vessel's stern-post, gave a much less resistance at equal speed of vessel than the four-bladed screw when held stationary with two of its blades in the vertical and the other two in the horizontal position.

Sixth. The two-bladed screw under the conditions of fifth, also gave a much less resistance than the four-bladed screw with its blades equispaced around the axis, and held stationary at the angle of 45 degrees with the perpendicular.

Seventh. The two-bladed screws, when held stationary with their blades in the horizontal position square across the vessel, gave resis-

tances, at equal speed of vessel, in the direct ratio of the fraction of pitch of which they were composed, all other things being the same.

Eighth. The two-bladed screws, when held stationary with their blades in the vertical position immediately behind the stern-post of the vessel, gave, at equal speed of vessel, resistances increasing with the fraction of pitch of which they where composed, other things being the same. The ratio of this increase in function of fraction of pitch, the experiments were not sufficiently numerous and varied to determine.

Ninth. The two-bladed screws, with the exception of the extreme case in which a two-bladed screw is employed composed of such small fraction of the pitch that its projected area on a plane at right angles to the axis is covered or masked by the stern-post of the vessel, gave, when freely revolving, resistances in the direct ratio of the fractions of the pitch of which they were composed, all other things being the same.

Tenth. That with the exception of the extreme case above defined, the two-bladed screws, *ceteris paribus*, composed of whatever fraction of the pitch they might be, make, when revolving freely, at any speed of the vessel greater than $3\frac{1}{2}$ geographical miles per hour, the same number of revolutions per mile. As the product of this number of revolutions and the pitch in feet is always less by a constant quantity than the geographical mile in feet, the two-bladed screws, composed of whatever fraction of the pitch they might be, are, for equal speed of vessel, dragged bodily at equal speed through the water.

Eleventh. That in the extreme case above excepted, the two-bladed screw of such small fraction of the pitch that its blades are masked or covered by the stern-post of the vessel, makes, when revolving freely, the same number of revolutions per mile at all speeds of vessel above $3\frac{1}{2}$ geographical miles per hour; but this number is less than when the fraction of the pitch is greater, and this screw is consequently dragged bodily through the water at a greater speed than in that case, and has a corresponding greater resistance in proportion to its fraction of pitch.

Twelfth. The four-bladed screw with its blades equispaced around the axis and held stationary at angles of 45 degrees with the perpendicular, gave 8·7 per centum more resistance than when it was held stationary with two of its blades in the vertical position and the re-

maining two in the horizontal position. The above proportion, however, is only true for the particular fraction of pitch of which this screw was composed. It will become less for greater fractions and more for smaller ones. It nevertheless shows that the resistance of a blade, even when at the angle of 45 degrees with the perpendicular is much less than when in the horizontal position. Had the resistance of the blades in both these cases been equal, the resistance of the screw, with its blades at the angle of 45 degrees with the perpendicular, would have been 440 pounds when the vessel had the speed of 7 geographical miles per hour, whereas the experimental resistance at that speed was only 337 pounds, or 76·6 per centum of the former. The difference strikingly illustrates the effect exercised upon the resistance of the blade by the proximity of the hull.

Thirteenth. The four-bladed screw with its blades equispaced around the axis, gave a much less resistance when revolving freely than when held stationary in any position. And when identical with the two-bladed screw in all respects except the number of blades into which the same surface was divided, it gave, when revolving freely exactly the same resistance as the two-bladed screw when revolving freely at the same speed of vessel.

Fourteenth. The above four-bladed screw makes, when revolving freely at any speed of vessel greater than $3\frac{1}{2}$ geographical miles per hour, the same number of revolutions per mile; and this number is exactly the same as that made under the same conditions by a two-bladed screw of the same diameter and pitch, with a fraction of pitch sufficiently great not to be masked by the vessel's stern-post; As the product of this number of revolutions and the pitch in feet is always less by a constant quantity than the geographical mile in feet, the four-bladed screw is dragged bodily through the water at a speed which is always the same per centum of the vessel's speed, let the latter be what it may.

Fifteenth. The Mangin screw composed of two identical two-bladed screws placed one immediately behind the other, so that, when viewed in projection on a plane at right angles to axis, it appears like a single two-bladed screw, gave, at equal speed of vessel, when of the same diameter, pitch, and *projected area* on a plane at right angles to the axis as the two-bladed screw, exactly the same resistance as the latter under all the conditions of being held stationary with the blades in the vertical position immediately behind the vessel's stern-

post, of being held stationary with the blades in the horizontal position square across the vessel, and of revolving freely. But the Mangin screw, composed as above, has double the fraction of pitch and double the surface of the two-bladed screw above described; consequently, while the propelling efficiency will be greater than that of the two-bladed screw in the ratio of the square root of 2 to the square root of 1, its resistance at equal speed of vessel when dragging with its blades held stationary in any position, or revolving freely, will be only one-half of that of the two-bladed screw.

Sixteenth. In the cases of a two-bladed screw, a four-bladed screw, and a Mangin screw, all three having the same diameter, pitch, and fraction of pitch, or, in other words, being identical except as to number and arrangement of blades, their propelling efficiencies in smooth water are equal, but their resistances when dragging at equal speeds of vessel are very different. When these screws are revolving freely the resistances of the two-bladed and four-bladed are equal, while the resistance of the Mangin screw is only one-half of that of either. When these screws are held stationary and dragged through the water, the resistances, at equal speed of vessel, of the two-bladed screw and of the Mangin screw with their blades in the vertical position immediately behind the vessel's stern-post, and of the four-bladed screw with two of its blades in the vertical and the other two in the horizontal position, these positions for the three screws being those in which they have the least resistance when held stationary, compare as 100 for the Mangin screw, 219 for the two-bladed screw, and 344 for the four-bladed screw. As regards to the latter, however, this proportion is true only for the particular fraction of pitch (0·3570) of which these screws were composed. With larger fractions of the pitch the resistance of the two-bladed and four-bladed screws would be relatively less, and with smaller fractions of the pitch it would be relatively more, but in a higher degree for the four-bladed than for the two-bladed screw.

All these screws give the same number of revolutions per mile when revolving freely so long as the projected area of the Mangin screw on a plane at right angles to the axis is sufficiently large not to be covered or masked by the vessel's stern-post, and this number is constant at all speeds of vessel above three and a half geographical miles per hour, at which revolution ceased.

Seventeenth. The Griffith screw, though of the same diameter as the others, had a pitch so different in kind and dimensions, and blades

so different in number and shape, that no comparison can be made with them. There can only be drawn the general conclusion, that screws with larger pitches when revolving freely, make fewer revolutions per mile and have the product of that number of revolutions and the pitch in feet a greater proportion of the mile in feet than screws of smaller pitches.

Eighteenth. The foregoing conclusions, though qualitatively exact for the kind of screws experimented with, let their absolute dimensions of diameter, pitch, and friction of pitch, be what they may, so long as these remain the same for all, and let them be applied to what form or dimensions of vessels they may, yet quantitatively will be modified by all the circumstances just enumerated, with the exception that whether the same kind and quantity of surface to be arranged in two blades, four blades equispaced around the axis, or four blades with two immediately behind the other two, as in the Mangin screw, the resistance when dragging and revolving freely will be as stated in sixteenth; and that they will all make the same number of revolutions per mile of the vessel's speed.

In the following Table No. 1, will be found the dimensions of the experimental screws, which, though given in the preceding report on their propelling efficiencies, are here re-inserted for conveniences of reference.

In the succeeding Table No. 2, will be found collected under appropriate headings, the numerical results of the experiments made with the screws dragging under various conditions.

Table No. 1, containing the principal dimensions of the screws employed in the foregoing experiments.

Designation of the screws.	Diameter, in feet.	Diameter of hub, in feet.	Pitch, in feet.	Number of blades.	Length of each blade in direction of axis, in feet.	Fraction used of the pitch.	Projected area of the blades on a plane at right angles to axis, in square feet.	Helicoidal area of the blades in square ft.
A.....	4·3333	0·50	5·136	2	0·9167	0·3570	5·1950	6·1321
B.....	4·3333	0·50	5·136	2	0·7187	0·2799	4·0730	4·8078
C.....	4·3333	0·50	5·136	2	0·4583	0·1785	2·0975	3·0661
D.....	4·3333	0·50	5·136	2	0·2604	0·1014	1·4755	1·7417
E.....	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
F*.....	4·3333	0·50	5·136	4	0·4583	0·3570	5·1950	6·1321
H†.....	4·3333	1·25	7·000	3	‡0·9167	§ 0·2034	2·7495	4·2068

* Mangin or duplex screw. † Griffith screw, with expanding pitch from 6¾ ft. to 7⅓ ft.
‡ Maximum. § Calculated for the mean pitch of 7 feet.

Table No. 2, containing the results of the trials made to ascertain the dynamometrical resistances of the experimental screws of the United States steam-launch No. 4, when it was towed by the steamer Monterey, with the screws dragging under the different conditions of revolving freely by the pressure of the water on the forward side of their blades, and of being held stationary in different positions.

Kind of screw, and conditions of its trials.	Designation of the screws.	Speed.				Resistances.				Loss of vessel's speed due to the drag of the screw.		
		Speed of the vessel, in geographical miles per hour.	Number of revolutions made by the screw per geographical mile.	Speed of the screw, in geographical miles per hour, calculated from the pitch and the revolutions.	Difference, in per centum of the speed of the vessel, between the speed of the vessel and the speed of the screw.	Resistance of the vessel alone—i.e., without any screw—in pounds per dynamometer.	Resistance of the screw alone, in pounds per dynamometer.	Aggregate resistance of vessel and screw in pounds per dynamometer.	Resistance of the screw, in per centum of the resistance of the vessel alone.	Speed, in geographical miles per hour, that the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.	Loss of speed in geographical miles per hour, due to the resistance of the screw.	Loss of speed due to the resistance of the screw, in per centum of the speed the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.
2-bladed screw:												
Revolving freely by the pressure of the water	A	7	921	5·441	22·28	631	134	765	21·24	7·7075	0·7075	9·18
Held stationary, with the blades vertical behind the stern-post	A	7	....	.....	.....	631	350	981	55·47	8·7281	1·7281	19·80
Held stationary, with the blades horizontal, square across the vessel.	A	7	....	.....	.....	631	440	1,071	69·73	9·1196	2·1196	23·24
2-bladed screw:												
Revolving freely by the pressure of the water	B	7	921	5·441	22·28	631	105	736	16·64	7·5600	0·5600	7·41
Held stationary, with the blades vertical behind the stern-post	B	7	....	.....	.....	631	197	828	31·22	8·0186	1·0186	12·73
Held stationary, with the blades horizontal, square across the vessel.	B	7	....	.....	.....	631	345	976	54·68	8·7058	1·7058	19·59
2-bladed screw:												
Revolving freely by the pressure of the water	C	7	921	5·441	22·28	631	67	698	10·62	7·3623	0·3623	4·92
Held stationary, with the blades vertical behind the stern-post	C	7	....	.....	.....	631	90	721	14·26	7·4826	0·4826	6·45
Held stationary, with the blades horizontal, square across the vessel.	C	7	....	.....	.....	631	220	851	34·86	8·1292	1·1292	13·89
2-bladed screw:												
Revolving freely by the pressure of the water	D	7	757	4·472	36·12	631	54	685	8·56	7·2934	0·2934	4·02
Held stationary, with the blades vertical behind the stern-post	D	7	....	.....	.....	631	26	657	4·12	7·1428	0·1428	2·00
Held stationary, with the blades horizontal, square across the vessel.	D	7	....	.....	.....	631	125	756	19·81	7·6820	0·6820	8·84
4-bladed screw, blades equidistant:												
Revolving freely by the pressure of the water	E	7	921	5·441	22·28	631	134	765	21·24	7·7075	0·7075	9·18
Held stationary, with one pair of blades vertical and other horizontal	E	7	....	.....	.....	631	310	941	49·13	8·5483	1·5483	18·11
Held stationary, with the blades at the angle of 45 degrees with the vertical.	E	7	....	.....	.....	631	337	968	53·41	8·6696	1·6696	19·26

Table No. 2, containing the results of the trials made, etc.—Continued.

Kind of screw, and conditions of its trials.	Designation of the screws.	Speed.				Resistances.				Loss of vessel's speed due to the drag of the screw.		
		Speed of the vessel, in geographical miles per hour.	Number of revolutions made by the screw per geographical mile.	Speed of the screw, in geographical miles per hour, calculated from the pitch and the revolutions.	Difference, in per centum of the speed of the vessel, between the speed of the vessel and the speed of the screw.	Resistance of the vessel alone—*i.e.*, without any screw—in pounds per dynamometer.	Resistance of the screw alone, in pounds per dynamometer.	Aggregate resistance of vessel and screw in pounds per dynamometer.	Resistance of the screw, in per centum of the resistance of the vessel alone.	Speed, in geographical miles per hour, that the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.	Loss of speed in geographical miles per hour, due to the resistance of the screw.	Loss of speed due to the resistance of the screw, in per centum of the speed the vessel would have had with the screw removed, had the vessel been towed by the pull of the aggregate resistance of vessel and screw by dynamometer.
4-bladed screw, Mangin's system:												
Revolving freely by the pressure of the water	F	7	921	5·441	22·28	631	67	698	10·62	7·3623	0·3623	4·92
Held stationary, with the blades vertical behind the stern-post	F	7	....	.....	.....	631	90	721	14·26	7·4826	0·4826	6·45
Held stationary, with the blades horizontal, square across the vessel.	F	7	....	.....	.....	631	220	851	34·86	8·1292	1·1292	13·89
3-bladed screw, Griffith's system:												
Revolving freely by the pressure of the water	H	7	665	5·3541	23·51	631	125	756	19·81	7·6620	0·6620	8·64
Held stationary, with one blade placed vertically below the shaft, and the remaining two blades above the shaft at angles of 60 degrees from the vertical	H	7	....	.....	.....	631	283	914	44·85	8·4247	1·4247	16·91
Held stationary, with one blade placed vertically above the shaft, and the remaining two blades below the shaft at angles of 60 degrees from the vertical	H	7	....	.....	.....	631	361	992	57·21	8·7768	1·7768	20·24
Held stationary, with one blade placed horizontally on one side of the vessel's stern-post, and the remaining two blades on the other side at angles of 60 degrees from the vertical	H	7	....	.....	.....	631	331	962	52·46	8·6431	1·6431	19·01

PNEUMATIC TELEGRAPHS FOR LONG DISTANCES.*

Paper read at the Meeting of the Society of Civil Engineers of Paris, on the 4th of June, 1875.

By M. A. CRESPIN.

[Continued from Vol. lxx, page 285.]

In the present state of the question it seems evident that, even taking into account a postal service already well developed, the diameter of a pneumatic tube should never exceed one-tenth of a meter; under these conditions the limit of remunerative cost has been reached, beyond this limit the cost becomes greater than that of a railway. If such a tube is worked by engines of sufficient power, it can transmit as many as 100 boxes per hour, representing nearly 100 kilograms weight of messages, which, divided into letters of 20 grams each, would equal 5000 of such letters per hour.

It is evident that a traffic of this kind would be far in excess of the amount of work possible at the present time.

We have just seen by what has been previously stated on the subjects of pressure and diameter, that these two elements in the establishment and working of a pneumatic tube, cannot, practically, be extended beyond certain limits; we now proceed to examine the influence of the length itself. We again revert to the fact that all the advantages of a pneumatic telegraph consist in its compensating, by its capacity, for its relative slowness as compared with electricity. It is necessary therefore, if we wish to go far, to go at a high speed; we have just seen within what limits we can avail ourselves of increased pressure and diameter, and the result of our examination is, that a solution of the problem must be sought in some other direction.

The first investigations of the subject date from 1857; they were made by Mr. Latimer Clark, who brought forward the question of the necessity for a mechanical arrangement to allow of the working of lines of comparatively great length. A kind of opening was arranged which was closed by means of special mechanism at the moment a train passed, when a train was being impelled by compressed air, and was opened upon the passage of a train in the opposite direction, drawn inwards by the vacuum.

The advantages of a plan of this kind were indisputable, and we find in the journal *Engineering* of the year 1869 the description of an apparatus proposed by Mr. Sabine, which affords a satisfactory solution of the problem.

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* Extracted from the *Telegraphic Journal*, London.

Mr. Sabine has taken the case of a line similar to one of the principal line radiating from the Post Office in London, and constituting a line of communication with a point more or less distant by means of trains alternately driven forward by pressure of air, and afterwards drawn back again by a vacuum applied at the end of the tube terminating in the central station.

His arrangement consists of a valve acted upon through a hinged rod by a sort of diaphragm of leather or india-rubber, the latter being influenced through a special tube by the vacuum or pressure at the central station. This diaphragm opens the valve, and when sending by pressure the air, by escaping through the opening, allows the train to traverse the first section as if the line consisted merely of the length between the starting point and the valve. The moment the train passes the opening, it detaches the valve from the rod which connects it with the diaphragm, by the action of a spring; the valve then closes, and the train passes through the second section with the speed proper to a line having the length of the two first sections, and so on.

If the central station draws a train from the extreme end, the apparatus acts in the following manner: by means of the vacuum actuating the diaphragms through the special tube, all the valves are closed, the line can then be exhausted of air in front of the train which, as it passes the valves, acts upon the bolts, and thus disconnects them, so as to allow the air to enter behind the train at the end of each section; the same advantage is thus obtained as when sending by pressure.

The table given below shows the advantage gained by employing this apparatus; a line of ten sections is taken for example.

No. of Section.	Time of transit in each section.	Total time of transit. With Valve.	Total time of transit. Without Valve.	Percentage of gain.
1	1	1	1	
2	$\sqrt{2}$ 1·41	2·41	$2\sqrt{2}$ 2·82	17
3	$\sqrt{3}$ 1·73	4·14	$3\sqrt{3}$ 5·19	25·4
4	$\sqrt{4}$ 2·00	6·14	$4\sqrt{4}$ 8·00	30·3
5	$\sqrt{5}$ 2·24	8·38	$5\sqrt{5}$ 11·20	33·7
6	$\sqrt{6}$ 2·45	10·83	$6\sqrt{6}$ 14·70	35·7
7	$\sqrt{7}$ 2·65	13·48	$7\sqrt{7}$ 18·55	37·6
8	$\sqrt{8}$ 2·83	16·31	$8\sqrt{8}$ 22·64	38·8
9	$\sqrt{9}$ 3·00	19·31	$9\sqrt{9}$ 27·00	39·8
10	$\sqrt{10}$ 3·16	22·47	$10\sqrt{10}$ 31·60	40·6

From this table it is seen that the percentage of gain goes on increasing as the line becomes longer; the gain which is 17 per cent. for a line of two sections, with only one apparatus in the middle, increases to 40 per cent. upon a line of ten sections provided with nine of the apparatus distributed throughout its length.

The remedy is, however, far from being a radical one, for, if it allows pneumatic lines to be extended in length, it limits this extension, and the same table which shows the advantage of the apparatus, shows also very clearly the limit of the same extension; for we see that even with the proposed improvement it takes 3·16 times the time to traverse the tenth section that is necessary to pass through the first, and that averaging the gain over the whole length, the mean time occupied is represented by 22·47 instead of 10, which would be the figure were all the sections traversed at the same speed as the first. The mean speed after the tenth section has been passed in less than one half; the time occupied is nearly three times what it ought to be.

The solution of the problem of a line of unlimited length with a constant speed required a more complete apparatus, and it is this apparatus to which I have given the name of *relay*, that I am about to describe. Its object is to perform in the most complete and exact manner the operations which would be carried out by an attendant who, under conditions about to be described, would have to act in the following manner.

The pneumatic line of extended length has been, as in the case of lines established within the limits of cities, divided into sections of about one thousand meters in length; each of these sections is furnished at its commencement with reservoirs in which is stored up the compressed air, having the pressure and volume necessary for performing the service of the section. The case is exactly the same as that of an intermediate station in a city, provided with means for compressing air; the two lines up and down are arranged in a straight line, end to end, in such a way that a train received on the up line can pass without impediment into the down line; the attendant, whose presence we assume, would await the arrival by the up line of a train which was being sent to him, allowing to the air to escape freely at the end of the section. At the moment when the train passes from the up line into the down line he closes the former behind the train, and opening a cock communicating with his own reservoir of compressed air, by this means drives the train forward along the next section;

he keeps the cock open whilst the train is passing to the next station, and closes it when informed of its arrival at the latter point by the attendant there in waiting.

Such are the various operations which must be performed automatically by the relay; the first apparatus used and giving certain results was tried in the month of May, 1873. The trials were made in Paris, upon the direct line from the Central Station to the Bourse; and in London, in the engine-room at Telegraph-street.

At Paris the apparatus was placed under a cast iron plate, and was connected by special pipes with the reservoirs of compressed air in the station at the Théâtre Francais.

This apparatus fulfilled exactly all the operations above described as having to be performed by the attendant supposed to be placed at the intermediate station. The escape of the air took place in front of the relay, where a portion of the tube was perforated on all sides so as to give a passage to the air equal to twice the section of the tube. The closing of the line behind the train, and the opening of communication with the compressed air reservoirs were governed by a kind of trigger, and acted upon by the train directly it had passed through the relay. The duration of the blowing was determined by a piston rising in a cylinder through the effect of the internal pressure; the rising of this piston was regulated by the counter-pressure in such a way that the blowing continued somewhat longer than the time necessary. The moment a train arrived at its destination or entered a further section the pressure being destroyed in the line the weight of the regulating piston caused it to fall and remain in position to await the arrival of another train.

The success of this apparatus was complete; it enabled a certain number of trains to be passed to and fro between the Central Station and the Bourse with a saving of more than half the time. The return journey was equally rapid, for the trains were sent by pressure as far as the relay, the escape of air taking place through the perforated part of the tube; the rest of the journey was accomplished by means of vacuum from the Central Station.

The objection made to this apparatus is its delicacy; it contains within it a piece easily broken, this piece is the valve employed to close the line; if a foreign body hinders, even partially, its action the relay becomes nothing but an obstacle preventing, in the most absolute manner, the passage of the trains.

To remedy this objection it becomes necessary to do away with this valve which, after the description which has just been given, would seem to be the essential feature of the apparatus, since it is that which separates the outlet from the inlet. It could only be removed by suppressing the outlet, and to enable the latter to be dispensed with, the counter-pressure must be taken away.

It is this chain of observation which has guided me to the formation of the plan which I now proceed to set forth, and which completely solves the problem. The line is double acting; by means of special apparatus which are also relays, it is kept constantly exhausted of air and there is consequently no longer any counter-pressure nor are there any valves in the pressure relays.

By the side of the line, which we may assume to be of unlimited length are laid two secondary tubes connecting the reservoirs of vacuum and compressed air for the supply of the relays, which are placed in convenient positions along the course of the line. These relays are of two kinds; those destined to exhaust the line of air are placed five kilometers apart where it is intended that trains shall be sent along the line at intervals of a quarter of an hour. The reason for their being placed at this distance apart is, that a rather less space of time is needed for exhausting five kilometers, and there is, therefore, no advantage gained by placing them nearer together. They are of a very simple form, a piston rising in a cylinder carries with it a valve closing the line, and a slide opens the communication with the vacuum reservoirs; the piston is raised in the cylinder on the passage of a train, by the counter-pressure which follows the moving power, it closes the line behind it, and at once starts the exhaustion of the section of line which has just been traversed by the train. The valve of this relay has none of the objections attaching to that of the former relay, seeing that it opens of itself after the exhaustion of the section appertaining to the vacuum relay has been completed, an operation which is generally accomplished in half the time prescribed for the interval between the passage of two trains. Moreover, as these relays are placed every five kilometers, and at least one half of them are in places provided for compressing and exhausting the air, they are under the eyes of the attendants. The pressure relays placed one kilometer apart become simple blowers, opening on the passage of a train, and blowing all the time the train is traversing the section;

they merely consist of a piston pushing a counter-weight acting upon a slide, which is the pressure slide, and the regulating piston which stops the admission of air after the blowing has lasted the proper time; the compressed air enters the line by a kind of grating which uncovers openings having twice the sections of the line, and the blowing is governed by the train itself which, acting upon a trigger, lets fall a counter-weight placed upon the piston working the slide. The blowing is instantaneous; it is stopped by the action of the regulating piston which closes the communication leading to the line, and shuts up the compressed air in a small chamber between the point where the communication is thus closed and the slide. The effect of this compressed air at the moment when the pressure is lost in the line, that is to say, at the moment when the train has passed through the section, is to raise the piston acting upon the slide, and to restore everything into position for the arrival of another train. This apparatus, which is the main feature of the new system, is extremely simple, and does not require personal supervision in its working. It is accompanied by a reservoir of compressed air of sufficient capacity for the section.

I need not here discuss in detail the means by which the compressed air and vacuum are to be brought to the reservoirs serving the relays. Any of the methods usually employed for this class of work can be made use of, but the most economical process would, of course, be selected. In a populous country the engine stations might be numerous, and the power employed small. In thinly inhabited countries they might be 20 or 25 kilometers apart, and the power would then have to be greater.

I now proceed to the consideration of the speed with which the boxes will travel in a pneumatic line of unlimited length, in which, by the methods described above, the vacuum will be kept at 0·5 meters of mercury, and the pressure, admitted by the relays at intervals of 1000 meters, equal to 0·76 meters of mercury; the tube to be one-tenth of a meter in diameter.

My point of comparison will be the speed in the tubes of the Paris system, where a pressure of 0·4 meters of mercury gives a speed of 20 meters per second, in a line 1000 meters long, and 0·066 meters in diameter.

The increase of diameter will increase the speed in the proportion

$$\sqrt{\frac{100}{65}} \text{ or } \frac{10}{8}$$

say 25 meters per second.

The fact that the line if kept exhausted of air will reduce the friction in each length of 1000 meters to an average equal to that of 600 meters at most, for at the beginning of each section, that is to say, at the moment when the train passes the pressure relay, there is no column of air traveling with it; at the termination of the section only, will the column of air which drives the train have a length of 1000 meters. If the vacuum were perfect, the average friction length of the column of air would be but 500 meters. The diminution in the frictional length of the column of air gives an increase of speed in the proportion

$$\sqrt{\frac{1000}{600}} = \frac{33}{24}$$

The speed, raised to 25 by the increase of diameter, now becomes

$$25 \times \frac{33}{24} = 36 \text{ meters.}$$

We have then the increase of the differences of pressures, which is also in the ratio of the roots

$$\sqrt{\frac{26 + 50}{40}} = \frac{115}{65}$$

The application of this last ratio indicates a speed of nearly 70 meters per second.

This is an enormous speed, and would in all probability be attended with some inconveniences, but it is evident that we should work with the highest speed possible.

Now, observations made with trains running under similar circumstances at speeds of 40 to 50 meters, have shown that these practical speeds are quite admissible in regular working. It is only necessary to employ a very strong material, arranged in such a way that it alone shall wear without wearing the line; this end is attained by fitting the rubbing parts of the boxes with a softer metal than that composing the line.

The two ends of the line are provided with apparatus suitable for sending and receiving, in which precautions are taken to secure a

considerable slackening in the speed of the train when approaching its destination.

This effect is obtained by causing the air in front of the train to be compressed in the last hundred meters leading to the receiving apparatus; this compressed air is allowed to escape slowly in such a way that the train rises slowly into the apparatus.

Pneumatic lines with relays would certainly be a valuable means of communication for correspondence between distant places. The facility with which trains can be multiplied upon these lines without considerable expense, the speed which they can attain, and even the small net cost of the system, if too large a diameter be not employed, would make it one of the greatest utility to the Postal service.

The speed of transmission is three times that of the fastest railway train, if the stoppage of the latter are taken into account, and the establishment of the system upon lines where several days are required for exchange of letters, would evidently be of immense service.

A line of this kind has been proposed for establishing rapid communication between the Assembly at Versailles and the Ministerial offices in Paris; its execution would be a first step in this path, which is little known and which has been but little explored.

Useful Effect of Gunpowder in a Cannon.—M. De Saint Robert, in an article from his pen in the *Revue Scientifique*, gives the following calculation of the efficiency of a rifle cannon, the diameter of the bore of which is 7·5 centimeters = 3 in.—the shell of which weighs about 3·7 kilograms = 8·3 lb.—and the firing charge of which is 0·55 kilogram = 1¼ lb. It may thus be estimated:—Experiment has shown that the velocity of the shell when it leaves the mouth of the cannon is about 400 meters = 1300 ft.—per second. The height from which the projectile would have to fall to acquire this velocity is 8158 meters = 26,800 ft. Consequently the work actually done by the powder is equal to 30·185 kilogrammeters = 219,000 foot-pounds. On the other hand, Bunsen and Schischkoff have found by direct experiment that the heat envolved by the combustion of a kilogram of gunpowder is equal to 619·5 calories. Hence the heat evolved by the above charge of 0·55 kilogram is equal to 340·7 calories. The mechanical work corresponding to this amount of heat is 144,798 kilogrammeters = 1,050,000 foot-pounds. Comparing this, which is the possible mechanical work, with the actual work done on the projectile as given above, the ratio is 0·208 for the effectiveness of the cannon; that is to say, about 21 per cent.

ON THE NECESSITY OF A MECHANICAL LABORATORY; ITS PROVINCE AND ITS METHODS.*

By Professor R. H. Thurston.

1. *Introductory.*—There are few men of any considerable practical experience in engineering who have not felt the great need of some well established and reliable authority to which they could apply for special information, either purely scientific or more strictly professional, bearing upon unfamiliar details of their work.

Probably every man who has grown up in daily contact with any branch of mechanical industry has seen hundreds and often thousands of dollars expended in the effort to obtain such information, and has seen the result accomplished, and the information, valuable as it was to many besides those who acquired it, remaining unpublished. The world at large has been left as ignorant as before.

Repetition of the work by others has followed, and a similar expenditure of money has produced the same limited result. Where one thousand dollars properly expended in securing the desired knowledge would suffice, were the results properly communicated to the profession, ten thousand or twenty thousand dollars may be expended by as many independent experimenters, each ignorant of the other's work; and, after all, the hundreds of others who might have been benefited received no assistance.

In many other cases experiments have been carried on, and large sums of money expended upon them, without the slightest really new and valuable information being gained, either because the experimenters were unaccustomed to such work, and had but a vague knowledge of the real object to be attained, and still less knowledge of the proper method of obtaining it, or because of their unfamiliarity with the best methods of investigation, or in consequence of their ignorance of what had been already discovered and published by others.

*A paper read before the American Railway Master Mechanics' Association.

It often happens, also, that a long course of experiments or a most tedious, elaborate, and expensive investigation is comparatively barren of results, in consequence of some apparently slight neglect which would not have occurred had the investigator been accustomed to such accurate work as is required.

Again, it has very frequently happened that engineers have remained for many years in ignorance of the real nature of some familiar phenomenon, or of some important principle, simply because, in order to enable the subject to be intelligently studied in all its relations, its complete investigation required a comparison of experiments made in the chemical or the physical laboratory, with the work of the mechanic. The mechanical properties of materials; the effect of temperature upon the metals; the incrustation and corrosion of steam boilers; the value of lubricants; the heating power of fuels; all these, and many other subjects, require for their full investigation the highest talent of the chemist, and of the physicist, as well as of the engineer.

The serious necessity of the establishment of some great institution which should be solely devoted to the work of investigation of such scientific and professional problems as are daily being presented to the engineer and the mechanic, in the progress of regular work, was forcibly impressed upon the mind of the writer when—then but a boy amusing himself in the workshop and the drawing-room—he found himself unable to obtain accurate information upon even the most important subjects involved in the design of the steam engine, or in the proportions of its details, and especially information relative to those circumstances which determine the quality of the materials used. The size of a piston rod, the thickness of a cylinder head, the proportions of a crank pin, were usually determined, in nearly every shop, not by rules based upon careful investigation of the strength of the material, but by "rule of thumb." The economical value of high steam and of expansion, the influences of piston speed, the laws governing the deposition of the salts held in solution in spring water or in salt water; the effect of surface condensation on the efficiency of the engine and upon the durability of the boiler, are all subjects in regard to which engineers held widely discordant opinions. The real effect of heat and cold upon materials was uncertain, and the laws governing the resistance of metals to blows, it was asserted, were involved in mystery.

When, in later years, he was intrusted with sometimes important work, more light was the reward of painstaking investigation, but it came slowly and was most unsatisfactory from its meagerness. Experience in the management as well as design of engines and machinery at sea and on shore, revealed still more fully a great want of information in the most important branches of engineering work. We are getting on more rapidly to-day, but still too slowly.

Abroad, some valuable work has been done—far more than in the United States, although something has been done here. Our knowledge of the strength of materials rest, upon the researches of General Morin, of Tredgold, Hodgkinson, Fairbairn, and Barlow, of Chevandier, and Werthiem, and of Vicat. Kirkaldy, Styffe, and Bauschinger have made the latest and most valuable contributions from foreign sources. In this country, a committee of the Franklin Institute, and Captain Rodman and Major Wade of the Army, Chief Engineer W. H. Shock of the Naval Engineer Corps, and a few others, have done good work, while Commander Beardslee, United States Navy, has recently added important facts to those previously acquired. The experiments of Clark in England, of Bauschinger on the Continent, and of Forney in the United States, have thrown some light on the methods of distribution of steam in locomotives. The labors of Tresca, of Morin, and of Coulomb on the laws and facts of friction are the basis of our knowledge of that subject. Our own Professor Johnson gave us an immense amount of information relative to the values and characteristics of American coals; and Baron Von Weber has given us important knowledge relating to the permanent way, from experiments on European railroads. Thus we find that some valuable work has been done in every line of research which has become the standard that guides us in practical applications.

In nearly every case we shall find, on investigation, that the standard which conservatism insists upon our accepting as a guide in our work has been some time in existence, and that it is based upon experiments with materials which were quite different from those now in our markets, and that it was made when methods now perhaps obsolete were considered satisfactory. In every field of labor we therefore meet with more or less unexplored paths, and we find ourselves daily at a loss to determine the best method of doing our work. The best work which has yet been done in the most important branches of research has usually been of such a broad character, and has demanded

the expenditure of so much time and money that it has of necessity been done by governments or by wealthy corporate bodies.

Abroad we have in the French "*Conservatoire des Arts et Metiers;*" and in the laboratories of great technical schools of Europe, may be found men competent to do good work, and who are assisted by the pecuniary aid of their governments. It thus happens that we owe very much to them. In this country the same system which gives us political freedom operates against the successful prosecution of such work under the patronage of government. In matters of pure science, as in the work of the Smithsonian Institute, in that of the coast survey, and in the occasional astronomical or geological expeditions which are carried out at public cost, the difficulties are not so serious. But investigations which have a directly practical bearing are liable to fall into the hands of those who are not thoroughly well prepared for the work.

It seems very certain that a really successful and permanently useful institution, devoted to investigation, must be partially, if not entirely, sustained by private individuals legally responsible, and well known as qualified for their work.

2. *Methods and investigations.*—The method of operation in the prosecution of any investigation may be detailed in a few words:—

a. The investigator must first know definitely what phenomenon it is proposed to investigate. A vague desire to know more of any given subject is by no means sufficient to justify entering upon a work which may be found to be indefinite in its extent and infinite in its ramifications. As a rule, the more completely the work may be narrowed down the better. It must necessarily be ultimately resolved into one or more questions which may be stated with precision before any probably intelligent and remunerative work can be commenced.

For example: To determine the effect of cold upon rails and machinery, which has been so often attempted and which still remains to a considerable extent, an unsolved problem, we may find ourselves compelled to resolve this question into several, as, for instance:—

(1.) What is the effect of change of temperature upon the strength of pure iron?

(2.) What upon iron containing carbon chemically combined, *i. e.* steel?

(3.) What upon iron containing carbon mechanically combined?

(4.) What upon iron containing sulphur chemically combined?

(5.) What upon iron containing phosphorus?
(6.) What upon iron containing silicon?
(7.) What upon iron containing cinder?
(8.) What upon steel containing sulphur?
(9.) What upon steel containing phosphorus?
(10.) What upon steel containing silicon?
(11.) What upon metal containing mixtures of these substances in the various proportions frequently met with?
(12.) What is the effect of change of temperature upon the ductility of all these metals?

And when we speak of the effect of low temperature we must not forget that it may have, and in fact does have, an effect in at least two ways: It will affect the resisting power of a material, especially under shock, not only by the change of molecular force which is due to the change of the relative distances of the molecules, but also by the simple fact of change of density itself.

b. Having determined all of these several simple effects, it remains to collect them and to so group the results that the great law underlying their action may be detected; and then the often exceedingly difficult task arises of expressing that law mathematically, or in some other way, which may make the work practically useful. It is evident that this problem can only be solved by a combination of the intelligent efforts of the chemist and the physicist as well as of the mechanic.

Thus our simplest questions may, upon examination, be found to comprehend complex and often difficult problems, and may require for their solution the highest talent of not merely one man, but of a number of specialists, all of whose labors may be required to secure a satisfactory solution.

c. After deciding precisely what is to be learned, the next step is usually to ascertain how much has already been done of the work thus determined and limited. This usually requires a careful examination of the records of previous professional work extending far back into earlier times; and it frequently happens that a vast amount of valuable information may be gleaned, and the work immensely shortened, by studying the results already made public by native and foreign experimenters. Much of the finest and most practically valuable work of their kinds which has been yet accomplished will be found described in French and German engineering works and period-

icals. The long standard works of Morin and of others already mentioned are illustrations.

d. Next after the labor of examining and collating earlier researches, comes the planning of the new investigation proposed. This is as necessary a preliminary as is the designing of an engine before work is commenced upon it in the shop. A thoroughly considered and well matured plan of operation will usually prevent any serious errors involving expenditure of money, or, what is equally important, the loss of valuable time.

The formation of a plan of operations requires a very definite knowledge of the character of the problem and an accurate understanding of the relative importance and probable bearing of the anticipated results, and a knowledge of the facilities available for the investigation. It presupposes a knowledge of the adaptation, range, accuracy, and reliability of the apparatus to be used; and not less important than all this is the knowledge of the extent to which assistance must be asked of, and how far aid may be expected from, special researches of a more purely scientific nature. Skill in experimentation thus guided will then produce the best results attainable with the means at hand.

e. The next requirement is a proper collation and registry of results, a work in which there is opportunity to make useful a considerable degree of ingenuity and talent.

f. To make correct deductions from the records, is the final task, and this is an exceedingly important matter. A lack of knowledge of the subject or of collateral facts may destroy the value of the whole work.

This work being properly done and the account of the research being properly written out, a contribution to knowledge will usually be found to have been secured which has a value to the public, and sometimes to individuals, far exceeding that of the time and the money expended in securing it. Men of science have often devoted the best years of a life-time to the investigation of a single train of phenomena, seemingly insignificant in comparison with the great facts surrounding them; yet neither they nor the world think this a wasteful expenditure of time. The value of acquired knowledge is never to be measured by the value of immediately apparent results or of evident applications; yet, in the course of the practice of the engineer and the mechanic, it rarely happens that such experimental

work as he is compelled to take in hand does not bring an immediate and ample remuneration, while the ultimate benefit accruing is often immensely great in proportion to what is paid for it.

We usually find that we help ourselves by such work to a most satisfactory extent, and at the same time are enabled to give our neighbors of our light without sacrifice, and to experience the gratification of benefiting the profession and the public.

3. *Locating a mechanical Laboratory.*—The location of such an establishment as would be well adapted to general work of the kind here contemplated, and to the prosecution of special investigation of a directly or indirectly practical character should be carefully selected.

The necessity of frequently calling for advice and assistance of both practical and scientific men, and the desirability of securing accessibility will prevent its satisfactory operation if it is not located so as to be within reach of a large proportion of those most interested in its establishment and maintenance.

The necessity which will frequently arise of making accessory investigations of a scientific character, in various branches of natural science, will dictate its establishment, probably, in connection with some conveniently situated and well established technical institution of learning, provided with well stocked laboratories, conducted by men capable of appreciating the importance of the work and of properly pursuing such investigations and who will take an interest in the subject.

The institution should have a character which is readily defined. Its magnitude is not so easily determined. It may be of very limited extent, and may yet do a vast amount of good; or it may become a vast establishment, employing a large corps of able men, making use of extensive collections of valuable apparatus for machinery, and making profitable use of larger capital than the French "Conservatoire des Arts et Metiers," already alluded to, which has an annual income of nearly seven hundred thousand francs, five hundred thousand of which come from the state. In a large and growing country like ours, peopled by the most active and enterprising of every race, the future of such an institution, if properly managed, would be whatever its managers and those whom they aid might choose to make it.

Its stock of apparatus would be determined, in character and extent, by the nature of the work most imperatively needed. It

would probably comprise a set of machines for testing the strength and other no less important qualities of the materials of construction, dynamometric apparatus, instruments for testing lubricants, steam engine indicators, calorimeters, pyrometers and thermometers, and apparatus for determining the heating power of fuels. A mercurial gauge with the usual accessories for comparing standard gauges, standard weights and measures, instruments for determining specific gravity, and other well-known forms of experimental apparatus would be needed.

Special apparatus and instruments adapted to new methods of investigation and new fields of research would rapidly accumulate, as they might be constructed for special purposes or contributed from outside sources, and would ultimately form a collection of very great value. A small collection of machine tools would be needed for the purpose of preparing materials and of making or repairing apparatus.

4. *The personnel.*—The personnel of this establishment would probably consist of a Director who should be, if possible, familiar at once with the theory and practice of the profession of engineering. and who should also have as large a knowledge as possible of science, particularly in its bearing upon his work. He should have able assistants of similar qualifications, and should be able to appeal to men of science and to practical men alike for advice, with confidence that it would be given and that it could be profited by. Good mechanics to take charge of tools, to aid in preparing apparatus, and to assist in manipulation, and some unskilled labor would complete the list.

Such an institution as has been here briefly described, doing the work which is most immediately required by the various branches of manufacturing industry and of engineering, would be of incalculable benefit to mankind. As remarked by the writer in addressing the Trustees of the Stevens Institute of Technology on this subject, such an enterprise "would give to this country an institution such as has never yet been organized, and one whose value would prove beyond estimation. The accumulation of facts, the valuable application of science, and the directly practical bearing of the work which may be done, would in a comparatively short time be productive of richer results than have been attained in constructive science during many previous years. It would do most effectively that work which has hitherto been too much neglected, the application of scientific knowledge to familiar work and to matters of business. It would do much

to close up the space which so widely separates the man of business from the man of science, and would lead to a far more perfect system of mutual aid than has yet existed."

It would, by aiding the progress of improvement in our methods of work, and by the application of scientific knowledge in practical life, aid in the development of our material resources, lend a new impetus to the industrial enterprises of our people, and assist, to an extent which can probably hardly be conceived, in the promotion of our national prosperity.

A decade of such work as could and should be done, when such facilities are rendered available, may be expected to be more fruitful of practically useful results than a quarter of a century of unsystematic, desultory, and unorganized efforts, such as has hitherto been our only method of acquiring information.

5. *The Stevens Institute of Technology and its Laboratories.*—The convenient location of the Stevens Institute of Technology, its exceptionally complete collections, its special adaptation, in consequence of its organization as a School of Mechanical Engineering and by the training of its officers and employees to such work, has led gentlemen well known in connection with railroad work and with the iron and steel industries to ask whether it would be possible to induce its authorities to inaugurate such an institution as a part of its Department of Engineering.

The evident interest which the plan has awakened among all classes engaged in engineering and mechanical work induced the writer, who had long believed such a laboratory to be one of the necessities of the present time, to address the Trustees upon the subject. This correspondence, in which the case is stated by the writer, and in which the trustees acquiesce in the views presented with an interest and a promptness of action which exhibits a thorough appreciation of the importance of the subject, will be read with interest by every one.

The trustees of the Stevens Institute of Technology have consented to inaugurate a mechanical laboratory, and it is to be hoped that this germ, which is just now commencing its development, may grow into something as noble in itself and as grand in results as its most interested and enthusiastic friends can possibly have anticipated.

It is a pleasure to be able to announce also, that those who are most interested in the matter are taking prompt action in aid of the plan. The American Railway Master Mechanics' Association has its

standing committee, which is ready to do all that lies within its province, and it may be expected to give valuable aid and advice.

The American Society of Civil Engineers have taken similar action, and their committee stands ready to co-operate with other societies and with individuals, and to assist also by advice and active exertion in securing means for the inauguration of this important project.

Leading members of the iron and steel associations and of the press are taking an active interest in the subject, and the plan will be so thoroughly published that it must succeed if the advantages apparent are at all appreciated by those who are to be most directly assisted.

STEVENS INSTITUTE OF TECHNOLOGY.
Hoboken, N. J.

Gramme Machine.—The following is an interesting example of the use of the Gramme machine for lighting purposes. The premises (a large iron foundry in France) are lighted by four lamps, each in electrical union with a Gramme machine, which are placed adjacent to the foundry, and 1700 rotations a minute are effected by means of a steam-engine used in the ordinary work of the factory. Each set of carbons is surrounded by a diffusing globe, so that the light does not appear as blinding points, but as four large shining white globes. The area of the building is about 182 feet by 91 feet, and the lamps are placed at a height of 17 feet above the ground in the corners of a rectangle 70 feet by 46 feet. This arrangement is found to suit admirably; the intensity of the light is nearly constant, and scarcely any shadow falls, on account of the rays from the four lamps crossing each other's paths. The cost, as far as at present ascertainable, is estimated thus :—The carbon poles, 0·250 meter each long = 0·500 m. for every lamp; the section equaling 6 square m.m. The upper carbon is consumed in three hours, the lower in five hours; hence the two may be reckoned as burnt away in four hours, or 0·125 meter per hour per lamp. This, at 1·75 francs a meter, equals 0·22 franc per hour per lamp; and to this must be added an estimate cost of 0·04 franc for driving each machine. The total expense thus becomes 1·04 francs per lamp per hour, *plus* the interest upon the cost of the machine and charge for its wear and tear.

Chemistry, Physics, Technology, etc.

ON THE THEORY OF ILLUMINATING FLAMES.

By Karl Heumann.*

Synopsis of article by Henry Pemberton, Esq.

The views of different observers are widely opposed. Stein believes that the disilluminating effect of the admixture of indifferent gases is the result of dilution only, which permits the oxygen of the surrounding air entering the flame, and transforming all the carbon into carbonic oxide. R. Blochmann is of opinion that the cause of the disilluminating effect of neutral gases, is that a relatively smaller quantity of oxygen comes into contact with the combustible constituents of the flame; and that in the flame of Bunsen's lamp, the entrance of oxygen into the inner zone of combustion causes decomposition of the gas, giving rise to hydrogen and carbonic oxide; therefore, gases that under ordinary circumstances burn without illumination.

Frankland's hypothesis is that the illuminating power of the gas flame specially depends upon its degree of condensation. In opposition to these, F. Wibel shows that a flame rendered nonilluminating by air or an indifferent gas, becomes again brightly luminous when the "burner" is heated to redness. In this case, the dilution of the gases of the flame and the amount of the absorbed air are increased; nevertheless, the flame becomes luminous. Wibel draws conclusions from this, in direct opposition to the views of those above cited, and goes, I think, to the opposite extreme. His thesis urges that it is not the *dilution*, but the *cooling* of the interior of the flame by the entering gases, that robs it of light. This certainly cannot apply to the flame of the Bunsen lamp, for if he is correct, the Bunsen flame should be cooler than the luminous one, whilst daily experience proves that the blue burning flame possesses a much higher temperature.

The oxygen of the admixed air cannot be held to be the cause in this instance; for heating the burner could not alter the relation of the gases, yet the flame thereby becomes luminous. Perhaps it may

*From the *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Sept., 1875.

be suggested that the effect of heating the burner is to restore the temperature that had been lowered by the incoming oxygen, but this is contradicted by the fact that the flame mixed with air is much hotter than the luminous one. The possibility of a lower temperature is therefore not admissible.

It remains therefore to recognize as a fact that the dilution of combustible gases is one important factor, and can alone—without reference to the temperature—disilluminate the flame. It must be further admitted that a mixture of illuminating gas and an indifferent gas requires a higher temperature to become illuminating, than the undiluted gas alone does. Wibel's experiment does not therefore prove that the cooling of the flame is exclusively the cause of the disillumination, for by the admixture of indifferent gases its composition is very materially altered. The truth therefore may well lie between the opposing theories of the different observers, and the disillumination of a flame containing carburets by the introduction of air or an indifferent gas, depends not only upon the cooling effect, but also upon the dilution of the gases of the flame, which dilution may have formed a gaseous mixture needing a higher temperature to burn luminously than the illuminating (un?) diluted flame itself previously required.

The support that Wibel's theory derived from the behavior of a flame from coal gas and oxygen, is explained by my view in the most convincing manner. As Wibel found, such a flame is extremely difficult to disilluminate, because its temperature in the presence of pure oxygen is an extremely high one. The cooling effect produced by the cold oxygen entering, as well as the absolutely higher temperature required to enable the gaseous mixture to burn luminously, is nearly if not entirely compensated for by the intense heat produced by the concentrated, energetic combustion in the presence of pure oxygen; therefore the disillumination is rendered so much the more difficult. That it ultimately can be produced by a very strong stream of oxygen, and by means of a net of wire gauze, may readily be understood.

The introduction of pure oxygen in a suitable manner into a flame renders it very illuminating by producing an excessively high temperature, whilst the prejudicial dilution that would be caused if air had been used, does not occur. Too much oxygen or too little can produce the same conditions that dilution by an indifferent gas would do;

in the one case the oxygen penetrating the small flame and diluting it excessively, in the other the combustion being too languid to afford the needed temperature.

EXPERIMENTS GIVEN TO SHOW THE EFFECT OF EXCESS OR INSUFFICIENCY OF OXYGEN.

An inverted flask filled with oxygen; into it introduce a small gas flame from the jet of a blowpipe. At first the outer portion of the flame expands enormously, consuming the lighting part of the flame, which decreases until it becomes only a little bright point. After a time, when the products of combustion have diluted somewhat the oxygen, the bright point increases until it reaches the mantle of flame; the brightly shining flame presents then the appearance that it would do in ordinary air. Gradually the products of combustion dilute still more the oxygen, the temperature of the flame sinks still lower, the flame becomes blue, then nearly invisible, and finally goes out.

To show that *cooling* alone can render a flame non-luminous, direct a small luminous gas flame against the bottom of a platinum dish or capsule, so that the flame will spread itself and become *blue*. Thus far, this result cannot be attributed solely to the *cooling* effect, since spreading out the flame might also mix it with the air and dilute it. But if the capsule be heated on the opposite (upper) surface to redness with the powerful flame of a large Bunsen's burner held horizontally, then with the rising temperature of the capsule, the flame beneath it will become brighter and brighter, until it will finally reach its original brilliancy. The capsule must of course be clean and free from traces of soda from the fingers. This proves that the disilluminated flame is again made luminous, simply by the temperature of the metallic plate. If the Bunsen flame be withdrawn, the small gas flame will remain luminous for a short time, and then as the metal cools it will become again blue.

In these experiments the question has not here been discussed upon what chemical or physical changes induced by the dilution or cooling, the disillumination depends; nor has the disputed point whether the material that heated to redness becomes luminous—be it carbon or dense vapor—been touched upon; but as concerning the opposing theories whether cooling or dilution is the cause of disillumination, it seems to me decided that at least three different causes, each by itself, can cause disillumination. In most cases, two or all three act simulta-

neously. I give as the result of my observations that *disillumination can occur—*

a. By cooling.

b. By dilution. The mixture of illuminating and neutral gases can only burn luminously when the flame possesses a much higher temperature than the ordinary luminous gas flame.

c. By energetic oxydation of the illuminating material (experiment 1).

And the restoration of the lighting power will be produced

a. By access of heat (experiment 5).

b. By increase of the temperature of the flame produced by heating mixture of gases or of the indifferent gases before their combustion.

c. By dilution of oxygen with indifferent gases.

ON THE DISTANCE BETWEEN THE FLAME AND BURNER.

R. Blochmann first investigated the phenomenon that the flame does not immediately touch the burner of a gas jet nor the wick of a candle. This is seen more clearly with a small flame than with a large one. As the gas jet is turned down, the relative distance between flame and burner increases. The distance between is much increased when an indifferent gas is mixed, such as nitrogen, carbonic acid, etc. Blochmann thought therefore that the *dilution* was the cause thereof, and explained the fact of the greater distance by stating that a certain fixed proportion must exist between the combustible portion of the gas and the air, and as the diluted gas required more volume for the same combustible quantity, so must a greater volume thereof be mixed with the air before combustion would occur; that is to say, the space between burner and flame must be larger. This somewhat forced explanation of Blochmann is, I think, wrong, for any cold object held in a flame produces a space between the flame and it. This space is the larger, the more diluted the gas.

It is more easily blown out the more it is diluted. A flame diluted with much carbonic acid will stand several inches above the burner, and be blown out with the slightest puff.

If the burner be heated, the flame will approach the burner more and more nearly as the temperature increases. If surmounted with a platinum tube heated to redness, it will approach and attach itself to the bnrner. The opening produced in a diluted gas flame by a

cold iron rod will close in proportion as the rod be heated; if the rod be made red hot, it will close completely. The above may all be noticed in an ordinary gas flame, but not so clearly or decidedly.

The space between the burner of a diluted flame being larger, is dependent upon the fact that the temperature is lower; for at the instant of combustion the evolved heat has to spend itself through the mass of indifferent gas. As the heat of the flame is low, any cool object will extinguish it in its immediate proximity by the further reduction of temperature.

It is thus beyond doubt that in all these experiments the cooling effect produced by the burner or other introduced cold object, is the *sole* cause of the above mentioned intermediate space.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.†

[Continued from Vol. lxx, page 279.]

Siemens' instrument consists essentially of two concentric tubes of glass, the inner tube being lined with tinfoil within, and the exterior coated with the same material without. The inner tube is closed at one end, and is sealed to the outer tube in such a manner that an interval remains between them. The outer tube is drawn out at one end to a thin junction piece, and a similar one is fused to it at the other end. Oxygen circulates in the interval. If the wire ends of the Ruhmkorff's apparatus are brought in contact with the tinfoil coating of the tubes, the intervening space becomes luminous, and the oxygen present is ozonized. Rumine‡ in England and Low in France,§ patented, in 1872, a process for obtaining ozone by blowing cold air into the Bunsen flame. There is no information as to the results of this process.

A patent obtained in England, and specified far from clearly, for

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*"Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

†From the *Chemical News*.

‡Rumine, *Ber. Chem. Gesell.*, v, 123.

§Löw, *Ber. Chem. Gesell.*, v, 740.

obtaining ozone by boiling seaweed,* may be mentioned as a curiosity, and also the credulity with which ozone-baths, prepared in this manner, find a ready sale, in spite of, or perhaps rather on account of, their high price. It appears at any rate that an industrial method of obtaining ozone is hitherto an unfulfilled desideratum.

Only the highest branch of industry, that in which justly no price is considered too high, as its object is health, to wit medicine, has found the present method sufficient to allow of the application of ozone. The observation first published by Schonbein, "that the air of towns, and even of well-ventilated rooms in the country contains no ozone," has been subsequently placed beyond the reach of doubt by Andrews,† whilst Schonbein's conjecture as to the connection between epidemics and a deficiency of ozone is certainly unproved.

Latterly Lender has come forward as the advocate of the medical application and efficacy of ozone, which he recommends both as ozonized air and ozonized water in tuberculosis, rheumatism of the joints, glaucoma, asthma, gout, etc.‡ That his exertions have not met with the approval of the profession appears from a discussion of the Berlin Medical Society, Oct. 29, 1873, held under the presidency of Dr. Von Langenbeck.‖ Here the use of ozone was defended by Lender alone, and met with zealous opposition. O. Leibreich argued on this occasion that it was impossible to convey into the blood a body so unstable as ozone, which must be decomposed in the respiratory organs. Inhalations of ozone must, therefore, be merely inhalations of pure oxygen, whilst the disinfection of sick chambers may be effected by simpler and better means. Nevertheless, it is necessary to mention here the observations of Schone§ and Houzeau¶ and after working with ozone, its peculiar odor adheres to the hands for some time, as well as to garments of flannel or other tissues. Its decomposition, therefore, appears not to be instantaneous. That the physiological action of strongly ozonized oxygen is very important, appears from the recent experiments of Dewar and MacKendrick.**

Berl. Chem. Gesell., v, 543.

†Andrews, *Nature*, 1874, p. 366.

‡Lender, *Goschen's Deutsche Klinik*, 1872, 1873.

‖*Klinische Wochenschrift*, 1873, 588, 589.

§Schöne *Berl. Chem. Ges.* 1873, 1226.

¶Houzeau, *Ann. Chim. Phys.* (4,) xxvii, 16.

**Dewar and MacKendrick, *R. Soc Edinb. Proc.* Session 1873, 1874.

Oxygen ozonized by induction, and containing at most 10 per cent. of ozone, killed small animals which were allowed to inhale it, such as rabbits, mice, and small birds, the latter two in 20 minutes. Respiration was rendered slower, the pulse was enfeebled, and the blood in all parts of the body was rendered venous. This remarkable phenomenon is considered by the observers as due to the high specific gravity of ozone (24th,) which exceeds that of carbonic acid (22d,) and thus retards the diffusion of the latter out of the blood. The irritant action of ozone upon the mucous membrane and its destructive effect upon tissues are recognized both by these observers and by earlier authorities. Redfern considered in 1857 that in his experiments oxygen containing 1-240th of ozone proved fatal to small animals in 30 seconds, producing congestion and emphysema of the lungs after enlargement of the right ventricle.*

Lender has established an ozone manufactory for medicinal purposes. It is announced that ozone inhalations may be had at about 7½d. per cubic foot, or £1 per cubic meter. The method of preparation, and the strength in ozone, are not stated. Ozonized water, according to the degree of concentration, costs from 6d. to 1s. per bottle. This ozonized water was very carefully tested by Carius† with the unfavorable result that in 1000 grms., 0·0087 to 0·0095 grm., or less than 1-1000th per cent. of ozone, was present. Chlorine and hypochlorous acid were not detected. On the other hand, Behrens and Jacobsen‡ say that nothing but hypochlorous acid is found in commercial ozone-water. According to the experiments of Carius, the absorption coefficient of ozone in water is so small that the above-mentioned figures border very closely upon the highest possible quantity.

How great would be the influence of a cheap source of ozone upon manufactures appears at once from the fact that in the nascent state this body oxidizes nitrogen to nitric acid. The presence of the latter body in thunder-rain has long ago been found to result from this circumstance. The manufacture of ozone would, therefore, involve nothing less than the synthesis of this important mineral acid, hitherto only procured from nitre.

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*Andrews, *Nature*, 1874, 366.

†Carius, *Ber. Chem. Ges.* v., 520, *and* vi., 806.

‡Behrens and Jacobsen, *Vierteljahrschrift f. Pr. Pharm. von Wittstein*, xxii, 230, 1873.

That in grass-bleaching and in disinfection by means of ethereal oils we have from time immemorial made use of ozone—generated in the one case by the growth of grass, and in the other by the hydrocarbons—can only serve to intensify our longing for the technical production of ozone. Upon such a process depends the method of bleaching ivory, as it has been conducted since 1850 in Meyer's walking-stick manufactory at Hamburg, and subsequently at other places. The ivory is immersed for weeks in photogen, or other volatile oils, exposed to strong sunshine and to air, whereby the latter is ozonized and bleaches.

The first patent for the application of ozone was recently granted in England. In order to form acetic acid from alcohol without fermentation, the inventors* obtain ozone by blowing air through a flame and bringing it in contact with a current of alcohol. A practical verification of the procedure has not been furnished.

HYDROGEN.

Of the three properties to which the industrial applications of hydrogen are applicable two are of so striking a nature that they cannot have escaped the earliest observers. To them it appeared as the combustible principle, the "volatile sulphur;"† subsequently, it was regarded as the long-sought-for phlogiston,‡ or as the "inflammable air," of which all combustible gases were mere varieties. In modern times, this previously vague knowledge has been rendered definite, recognizing in hydrogen the greatest heat of combustion, and consequently the property of producing the highest degrees of heat and light, properties which met with a practical application at an early date.

The low specific gravity of hydrogen did not escape the earliest observers. Being scarcely ponderable, it excited the idea of imponderable bodies, and its specific lightness, as well as its great heat of combustion, soon met with a striking application.

A third attribute is of a less manifest nature. Occasionally destroying colors, but often obtained without any brilliant and striking phenomena, hydrogen in its nascent state is capable of entering into many combinations, of which it is incapable when pre-existing in a

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*Turner and Vanderpool, *Ber. Chem. Ges.*, vi, 1553.

†Lemery, "Memoirs de l'Académie," 1700.

‡Cavendish, 1766.

free state. It liberates chlorine, oxygen, and other elements from their compounds, and takes their place; or it is deposited in compounds not fully saturated, and fills up the vacancies. This attribute is most weighty for the most recent development of chemistry, as well as of great technological importance. Unawares, this property has been made use of for ages. Upon it depends the transmutation of indigo-blue in the vat into indigo-white, and, consequently, one of the oldest and most important branches of the art of dyeing.

(To be continued.)

THE THEORY OF VENTILATION.

Abstract from a paper in the Proceedings of the Royal Society, entitled, "On the Theory of Ventilation—An attempt to establish a positive basis for the calculation of the amount of fresh air required for an inhabited air space," by Surgeon Major F. De Chaumont, M.D.

This paper is the record of a very large number of observations made by the writer, with the assistance of two officers in the British service, in the rooms or wards of barracks and hospitals, chiefly at night, upon a basis of the evidence of the sense of smelling; the observations being accompanied with corresponding examinations of the constituents of the vitiated air. While, however, the "sense of smell" is made the ostensible basis of the theory, it is, in fact, merely used as a measure of the quantity of carbonic acid (CO_2) present, and an exceedingly elaborate set of computations and tables are made to bring into correspondence, and remove the error of observation which was found to attach to the relationship of the smell of odors, which have organic origin, with the presence of inodorous gas. The proportions of Vapor and Humidity, were also considered in the computations very fully, but with the result of extreme divergency, which attaches to the ratio of vapor in a normal atmosphere.

In the words of Doctor De Chaumont: "It is generally admitted that it is organic matter; either suspended, or in the form of vapor, that is the poison in air rendered impure by the products of respiration. It is also admitted, that it is the same substance that gives the disagreeable sensation described as "closeness" in an ill-venti-

lated air space. Although the nature of organic matter may vary to a certain extent, it will be allowed that a condition of good ventilation may be established if we dilute the air sufficiently with fresh air, so that the amount of organic matter shall not vary *sensibly* from that of the external air. Unfortunately, all the methods devised for the determination of organic matter in air, are both difficult and unsatisfactory, so much so, that they are almost practically impossible in a ventilation inquiry. Observations, however, as far as they have gone, seem to show that the amount of organic impurity bears a fairly regular proportion to the amount of carbonic acid evolved by the inhabitant of an air space, and as the latter can be easily and certainly determined, we may take it as a *measure* of the condition of the air space."

Notwithstanding this change of basis of investigation, the observations were really proceeded with on the original method of comparative odor, "closeness," the accuracy of which, does not, from the discrepancies of result, and the extreme profundity of the mathematical operations, in reconciling them with each other, strike one as very satisfactory for general use. The method of observation was as follows: "On first entering the room from the outer air (observations in prisons were not included in the investigation, because of the general difficulty of entering cells directly from the open air), the sensation was noted just as it occurred to the observer. Five grades of sensation were attempted, and denominated "fresh or fair," "not close," "close," "very close," "extremely close." The condition of the last two, however, proved so little dissimilar that they were necessarily merged, so that four grades of terms only remained. The air was then collected in two jars or bottles, and set aside with lime water for subsequent analysis, and the temperature of dry and wet bulb thermometers in the room, at the time of observation, was noted. Samples of the external air, with temperatures at about the same time were taken.

This statement of the nature and extent of each observation; when it is added that the number of observations reached 247, and of chemical analysis reached 473, and that all were tabulated and compared for elimination of varied results; will convey to the reader an idea of the extreme elaboration of study, which will be as satisfactory as an exhibition of the figures made in the steps of calculation. It is obvious, that to preserve any given condition of air in a continuously occupied room, by dilution; the supply of fresh air per given unit of time, must have a constant ratio to the quantity of impurity evolved by the inmates, in the same time; independent

from the size of the room, and equal to the assumed ratio of impurity of condition.* Dr. De Chaumont quotes as authorities for the volume of carbonic acid gas expired per hour, by a sleeping inmate of a room: Angus Smith, 0·405 cubic feet; Dr. Parkes, 0·600 cubic feet; Pettenkofer, 0·705 cubic feet.

Based on his results, and upon these authorities, the following table gives a comprehensive view of Dr. De Chaumont's figures:

Denomination of Sensation.	Limit of carbonic acid (CO_2) found in the air, per cubic foot; being the excess of carbonic acid over the mean external quantity of 0·0004.	Cubic feet of fresh air per inmate per hour needed to preserve the proportion of carbonic acid for the several grades.		
		Angus Smith's estimate, e = 0·405	Dr. Parkes' estimate, e = 0·600	Pettenkofer's estimate, e = 0·705
Fresh, fair, or not close..	0·0001831	2460	3280	3850
Rather close, a little smell	0·0003894	1155	1540	1810
Close.....	0·0006322	710	950	1115
Very close, bad, extremely close.....	0·0008583	530	700	825

The estimate of Dr. Parkes is approved by Dr. De Chaumont, and it is stated that the existing Army Regulations of Great Britain contemplate a delivery of 1200 cubic feet per head per hour, in barracks, and his sleeping hours are passed in an atmosphere to be rated between "rather close," and "close," to the sense of smell.

In considering separately the condition of barracks and of hospitals, it was found that in the latter, the "sense of smell" detected respiratory impurity, *accompanied by a far less proportion of carbonic acid.* Grouping the observations on each separately, there were for "fresh, fair, or not close," 0 000196 of carbonic acid present in each unit of volume of air in barracks, to 0·000157 in hospitals. Whence it follows that to preserve relative freshness of the two places, when 3000 cubic feet per hour is requisite for barracks, there will be 4000 cubic feet per hour demanded for hospitals. The condition of the air in the two cases, for less pure ratings in the demonstration of sensation, more nearly corresponded; so that on the whole list they very nearly coincided.

* In the shape of a formula this proportion becomes $d = \frac{e}{q}$ where d = volume of fresh air per inmate per hour, e = volume of carbonic acid expired per inmate per hour, and q = the limit of volume of carbonic acid admissible.

The final conclusions of the paper are as follows:

"*Conditions as to the Standard of good Ventilation.*

Temperature (dry bulb), 63° to 65° Fah.

do. (wet bulb), 58° to 61° Fah.

"N. B.—The temperature should never be much below 60°, but it may be found difficult to prevent its rising in hot weather. In any case, the difference between the two thermometers ought not to be less than 4° and ought not to exceed 5°.

"*Vapor* ought not to exceed 4·7 grains per cubic foot at a temperature of 63° Fah., or 5 grains at a temperature of 65° Fah.

"*Humidity* ought not to exceed 0·73 to 0·75.

"*Carbonic Acid*, respiratory impurity, ought not to exceed 0·0002 per foot. Taking the mean external air ratio at 0·0004, this would give a mean internal air ratio of 0·0006."

In review of this paper, it may be said, especially as applied to this country, that it is scarcely a satisfactory consideration of the necessities of ventilation in continuously occupied rooms. The connection between organic impurities and the presence of carbonic acid, is by no means as simple as here assumed. Recognizing that organic substances are either in suspension in the humidity or vapor in the air, or bear some more intimate relation to the humidity or vapor; in other words, that *they* are *not* independent gases, following the laws of diffusion; then, it follows, that *their* rate of absorption or diffusion varies in some ratio (perhaps not directly as) with that of the humidity or vapor.

The rate of diffusion of a vapor as compared with the rate of diffusion of carbonic acid, is exceedingly high. Taking, for instance, the average temperature between that of expired breath (90°), with that assumed by Dr. De Chaumont for the room, (65°) = 77½°; the tension of aqueous vapor is so low that its specific gravity becomes about 0·0196, while that of carbonic acid is 1·5290. As the rates of diffusion of the two gaseous bodies vary nearly as the reciprocals of the square roots of their densities; equal volumes of vapor, or of carbonic acid, would be diffused, in the ratio of 7·14 to 0·81. The best conclusion the writer of this article can reach, favors the presumption that about equal weights of moisture and of carbonic acid are evolved (in all ways) by the person; at rest or otherwise, in a uni of time. The volumes, therefore, to be dispersed are, in con-

sequence of the extreme levity of the vapor, as 78 to 1. It consequently requires 8·8 *times longer* to diffuse the vapor, than the time which is needed to diffuse the carbonic acid; and this ratio is further increased, by the difference of the relative rates of diffusion which would ensue from the presence of the different proportions of the gaseous bodies already in the air, to 10 or 12 times longer.*

Now, although the conditions of humidity for each observation have been carefully noted, compared and averaged in the paper, the final resulting ratios of organic impurity to carbonic acid present (whether the sense of smell be allowed as sufficiently accurate test, or the chemical analysis be accepted as the ground of the theory of ventilation) apply only to the average temperatures of 63° to 65° Fah., and corresponding humidity of 73 to 75 per cent. These conditions may subsist in England, or at least may not be differed from to the degree of affecting the average result, but in this country as in Northern or Eastern Europe, neither the external or internal temperature is supposable.

It would also have been much more satisfactory, if, with all the labor and care of making these observations, an estimate of real quantity of fresh air accompanying them had been recorded. It is stated to be sure, that "the army regulations contemplate 1200 cubic feet per inmate per hour, but practical inquiry has shown that this amount is generally fallen short of," but nothing is said from which the absolute quantity of fresh air, at any time of observation, can be inferred. The writer of this article, after inspection of the best English and French hospitals, is confident that this quantity of air is not usually supplied whenever the external temperature ranges below 50° Fah.

With little difficulty, it would be possible to arrange a room in England (or even in this country), from which; without change of air, and without removal of organic impurities, to any large extent; the carbonic acid would disperse freely. Conceive a room with the windows and doors tight and closed, and without opening at the bottom, but with an ample ventilation in the ceiling. This

* It must be noted that diffusion of vapor (when in gaseous, not vesicular condition) probably follows the laws of diffusion of gases, while evaporation from a moist surface is influenced (accelerated or retarded) in ratios of the tension of the vapor in contact with the surface; ceasing altogether when the tension is that due a saturated vapor, of the temperature of the moist surface.

ventilation might be guarded by gauge screens to preclude both currents, if the external and internal temperatures differed materially, but at mean temperature of nine months in the year, in England, no such guarding will be needed. In such a room no circulation of air from the outside would take place, while following the laws of diffusion, the ratios of carbonic acid and of nitrogen, after reaching some maximum of no large proportion; not much, if any, above the condition of "*fresh*," would become constant; while with the degree of saturation usual in England for nine months in the year, very little of the vapor of exhalation would be dispersed, but would merely be condensed on the walls and windows of the room in streams—absorbing in liquid form, the offensive organic substances.

This extreme suppositious case is a *type* of what actually occurs in hospitals in England, *in degree*. A limited ventilation is provided by inadequate supply, while ample discharge outlets admit of escape of carbonic acid by diffusion. Except the hospitals for the insane, the same defect subsists in general in hospitals, in this country; although the immense dryness of our winter air so promotes this diffusion of vapor, as to make our winter ventilation comparatively tolerable.

The assertion that 50 to 70 cubic feet of air per inmate per minute is requisite for dormitories in barracks or hospitals *might* be allowed to go unquestioned on the ground of the more of a good thing the better. Of course, if this quantity be taken as the *night* ventilation, at least one-half more is needed for the day supply of a sick ward. But any recommendation which carries with it an impracticability of performance, is likely to be as productive of harm as if it were absolutely wrong of itself. It is not necessary for the health of well or sick that they should exist in currents of air; it is not possible in mid-winter, in our climate, or in England to provide and heat such quantities. It is not feasible to arrange a building for any moderate or reasonable cost to admit them, and it may, without argument, be asserted that it is not desirable. The old device of the geometrician was "reductio ab adsurdum," and it will apply to-day. Any propositions which lead to such variance from possibilities must have erroneous data.

The probable solution is, let us get rid of the organic substance, and endure a little larger proportion of carbonic acid. We know the former to be deleterious and the latter to be innoxious. B.